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SVIC NOTES

NOISE REDUCTION

First, you might wonder why an editorial on noise reduction is appearing in a magazine concerned with shock and vibration. The answer is straightforward; in a great many cases in order to reduce noise, you must reduce vibrations. To be effective, then, the noise control engineer must be just as familiar with the techniques for solving shock and vibration problems as he/she is with solving acoustics problems. The good news is that recent developments in both structural dynamics, instrumentation, and acoustics have made the life of the noise control engineer much easier. In the remainder of this editorial I will briefly review recent major developments in the field of noise control and offer my views on just where we are heading.

Environmental and occupational noise control legislation enacted by the U.S. Government in the '70's stimulated a great deal of activity in noise control which in turn led to some major technical developments. Microprocessors and microcomputers revolutionalized acoustic data collection and analysis; the Fast Fourier Transform was, by itself, a major contribution. Powerful software was developed which allowed very sophisticated acoustic analysis to be made. Advances in both the finite element and the finite difference modeling methods made it possible to easily predict the vibration response of complex structures. Equally important were the advances made in modal testing techniques which provided the needed verification that the finite element modeling was "OK." The crowning achievement to all of this was the recent development of the two-microphone acoustic intensity measurement technique. This technique now makes it an easy matter to identify noise sources on vibrating structures. This provided an all important experimental link between structural vibration and noise reduction.

During much of the '70's the solution to a noise problem often involved the retrofit of existing equipment; the installation of barriers and shields and other ad hoc solutions were popular. Today, these solutions are viewed as being too costly. From now on the emphasis will be on solving potential noise problems in the design stage using computer aided techniques. Today, an engineer can sit down at a computer terminal and before they get up they can make a finite element model, apply a forcing function, predict the structural response and calculate the acoustic radiation. He/she can then modify the structure and recalculate all the steps until the radiated noise is acceptably low. And if, by chance, the problems are not solved in the design stage, the acoustic engineer has the option of analyzing acoustic intensity measurements made on an existing structure and recommending various fixes such as stiffening or damping the structure.

One final opinion I would like to offer; it may turn out that the greatest long-term contribution caused by the invention of the acoustic intensity measurement technique will be to give engineers a far better understanding of exactly how sound radiates from a solid into an acoustic media.

J.G.S.

EDITORS RATTLE SPACE

THE EFFECT OF MICROCOMPUTERS ON ENGINEERING

The microcomputer is going to have a pronounced effect on engineering as it is practiced today. Even though many engineers have used main frame computers for years, the accessibility of the microcomputer will heavily increase computer usage. In the past engineers were reluctant to use computers for various reasons: inaccessibility, cost, lack of software, or lack of knowledge about the computer. The advent of low-cost microcomputers and computer emphasis in engineering education have eliminated two major reasons for the low level of computer usage. Only the lack of software now stands in the way of all out computer usage. In my view the software will be developed as demands arise.

Of interest are the varied applications of the microcomputer to engineering -- from product design and development to manufacturing maintenance. Models of concepts provide insight into their feasibility and sensitivity to installation and maintenance. The availability of larger operating memories in microcomputers has made it possible to do finite element computation and drafting as well as computer-aided design.

At present, the computer is used to efficiently direct many manufacturing operations, including welding and machining. The number of such applications will grow as the power and versatility of computers increase. In the maintenance area engineers are using computers for monitoring and diagnostics. For the last five years microcomputers have been used to perform spectrum analysis with the fast fourier transform; however, the storage of large amounts of data in portable monitoring devices has not heretofore been possible. Recent computer developments include small portable devices that record, store, and process data. These devices will permit more comprehensive and versatile maintenance programs.

Hardware is now available to do all forms of engineering on the microcomputer. In the next few years more sophisticated software will have to be developed so that this hardware capability can be utilized. With the commercial opportunities that are available, I see no reason why a wide variety of good software should not be developed.

R.L.E.

SOUND INTENSITY MEASUREMENT

P.S. Watkinson*

Abstract. This article reviews the literature relating to sound intensity measurement, principally over the last three years and also includes significant earlier material. Principles, measurement errors, instrumentation, applications, and interpretation of measurements are covered. The applications considered are the measurement of sound power output by a source, transmission loss, absorption, source radiation characteristics, transient noise sources, and measurement in flow.

The advantages of direct measurement of sound intensity have been recognized for many years [1-5]. Because direct measurements cannot be made, certain assumptions about the relationships between intensity and some measurable field quantity are necessary; for example, the requirement of free field conditions to calculate sound power from pressure measurements. (Sound power is the integral of intensity over a surface, and intensity is proportional to the square of pressure for a single propagating planar wave.) Early instruments were not satisfactory principally because of unstable transducers and inadequate processing capability. Instrumentation technology has now matured sufficiently to stimulate active interest in the direct measurement of sound intensity; stable and accurately calibrated transducers and electronic components, digital processing techniques, and better understanding of sound field behavior have resulted in commercially available intensity measurement systems; Working Groups have been commissioned under ANSI (American National Standards Institute) and ISO (International Standards Organization).

The purpose of this review is to guide the reader through the literature that covers the most important developments in acoustic measurement techniques and instrumentation in recent years. The majority of the references date from 1981. Purposely omitted is the Proceedings of the 1981 Conference on recent developments in acoustic intensity measurement held at CETIM, Senlis, France; that Proceedings stands as a single reference for the state of the art to 1981.

PRINCIPLES

Sound intensity is a time average of the product of instantaneous acoustic pressure and particle velocity. It is a vector quantity due to the vectorial nature of acoustic particle velocity. The historic problem has been to measure pressure and particle velocity and preserve their relative phase; for a given magnitude, sound intensity will be a maximum if pressure and particle velocity are in phase and zero when they are in quadrature. Separate pressure and velocity transducer systems using either hot wire anemometry [3] or a ribbon microphone [2, 5] have not been satisfactory; the two microphone technique employed by Schultz [4] has proved the most attractive. This technique approximates pressure at a point midway between closely spaced microphones. The instantaneous sum of the two microphone signals and component of particle velocity in the direction along the axis joining the "acoustic centers" of the two transducers is obtained. The time integral of the instantaneous difference between the two signals is used. Signals proportional to pressure and particle velocity are available to be multiplied, time averaged, and calibrated to directly indicate intensity. Practical utilization and evaluation of this method in its analog sense have been discussed [6, 7].

Transformation of pressure and particle velocity approximations into the frequency domain allows sound intensity (as a function of frequency) to be directly related to the imaginary part of the cross spectrum between the two microphone signals. This relation was first published by Fahy [8] and later Chung [9], who also included a method for overcoming errors caused by phase mismatch between the two channels of the instrumentation. Mathur [10] recently published a more in-depth derivation of the cross spectral

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formulation; it is subject to fewer errors than previous formulations. The attraction of the cross spectrum method is that it can be implemented on a two channel fast Fourier signal analyzer. Certain new analyzers include a sound intensity package.

Basic techniques for acoustic intensity measurement have been the subject of a number of papers published in journals aimed at noise control engineers and thus serve as general introductions to the subject [11-16]. Also of interest is a recently described velocity transducer [17]. If this transducer were developed so that calibration is reliable and dynamic range is good, it might be possible to have separate pressure and velocity transduction for acoustic intensity measurement.

Measurement Errors. The two microphone technique of sound intensity measurement is subject to a number of inherent errors that impose fundamental limits on the measurement regime. A major problem is that these errors are field dependent and do not usually occur in practical situations. The plane wave case gives a feel for the nature of a particular error, and many investigators use this case to illustrate errors.

An error is introduced by two microphone approximations to pressure and particle velocity. This error has been discussed for the plane wave case [4, 6, 7]; other work also provides insight [18-20]. The work of Thompson and Tree [18] should not be read without reference to the work of Elliott [19] and Pope and Chung [20]; they point out typographical errors and limitations of the earlier work [18]. The error for a particular microphone spacing underestimates intensity as frequency increases. A minimum microphone separation is thus dictated by a particular upper frequency of interest and a maximum acceptable error. This error [21] and some practical measurements of its effect [22] have been described. These papers consider finite approximation errors for the plane wave case; the same error has been calculated for a piston-type source [23].

The finite approximation error derived for the near fields of simple sources (monopole, dipole, and quadrupole point sources) have been presented [18] and discussed [19, 20]. The conclusion is that the closer to the source the measurement is made, the greater the error. Minimum distances (in units of numbers of microphone separation) from sources have been recommended for a maximum 1 dB error [11, 19] although different minimum distances were recommended. These distances are only a few microphone separations; it has been pointed out [20] that, at such distances, very few real sources approximate simple point sources. Error in the estimation by the two microphone technique of particle velocity in the extreme near field of a vibrating plate has been discussed [24]; in this case the acoustic field ideally breaks down locally to waves of frequencies expected for propagation in air (at some angle to the wave of the plate) or of wavelengths equal to those in the plate (traveling parallel to the plate).

A mismatch in phase response between the two transducers and instrumentation channels produces an insidious error [7, 9, 11, 19, 21]. The fractional error is approximately (low frequency approximation) equal to the ratio of the phase mismatch to the phase difference between the pressures at the two microphones. In the plane wave case the expected phase angle between the two microphone pressures decreases linearly with decreasing frequency. In general, instrumentation channels have some low frequency cutoff that is not necessarily the same for both channels; there is thus an increasing phase mismatch with decreasing frequency in the low frequency region. The result for a given transducer spacing and maximum acceptable error is a particular low frequency limit. This low frequency limit can easily be one hundred times the low pass cutoff of the instrumentation; the limit is dependent upon microphone spacing and degree of mismatch. In addition, this error often displays a very sharp increase with decreasing frequency such that, although an acceptable low frequency limit can be ascertained, any drift or change in mismatch (e.g. after an accidental knock on one transducer) can dramatically increase the level of the error. Although it is particularly important at low frequency, the error

must not be ignored at other frequencies of interest. Some finite mismatch always exists over the entire frequency range and becomes significant for measurements in fields characterized by particularly small phase angles between the pressures at the two transducer locations.

Use of digital-based Fourier techniques allows analysis of the statistical errors associated with intensity measurement. Formulas for random error as a function of coherence, number of averages, and phase angle between the two pressure signals have been presented [25] and their applications discussed [19, 26, 27]. The random error is generally inversely proportional to this phase angle; coherence is often very close to unity; these factors can cause problems in calculating random error due to phase error for the former and resolution in the latter.

Distortion of a sensed sound field by the presence of microphones and mountings has been considered [4, 11, 22, 28-31]. These papers identify some upper frequency at which scattering and diffraction significantly affect measurement of intensity; the frequency and level of significance of the effect are strongly dependent upon the geometrical details of the microphone configuration used, so that generalization of results is difficult. Microphones and mountings have unique aspects of configuration, but the smaller the transducers and mountings, the higher the frequency at which the field distortion becomes significant.

Relevant to sound power determination using intensity measurements is the discrete implementation of the surface integral of intensity around a source. The discrete spatial sampling has been discussed as an analog to discrete time sampling [32]; a spatial Fourier transform was used to describe variation of the field through space. This variation is subjected to Nyquist sampling criteria, so that a minimum number of sampling points can be chosen to adequately represent a field. Sampling and choice of surface have been discussed [33, 35].

Calibration. Two characteristics of a two-microphone sound-intensity system require calibration. One is sensitivity. If each microphone and instrumentation channel is properly calibrated for pressure response [11] and if separation distance of the transducers and density of the medium are known, it must be assumed that the system is calibrated for intensity readings (Watts m^{-2}). There is no true independent check, however, because no known standard intensity source exists. Plane wave propagation can be approximated at a distance from a loudspeaker in an anechoic environment to provide some confidence in measurements.

The other calibration involves phase mismatch. This problem can be overcome [9] by taking the geometric mean of two measurements; one measurement is made with the microphones reversed in space compared with the other. Because this operation is difficult to perform accurately with a simple hand-held microphone mount, much effort has been directed toward measuring phase mismatch and correcting for it. A method in which the two microphones are mounted to sense the pressure at the end wall of a closed tube (acoustically excited at the other end) has been described [36]. Over a certain frequency range it can be assumed that the two microphones sense precisely the same magnitude and phase of pressure. Outside this ideal range a second measurement can be made by swapping the microphone positions and assuming that each microphone now senses the pressure that the other sensed on the first measurement. Manipulation of the two measurements yields the microphone phase mismatch. A problem relating to this technique [37, 38] is that, if the microphone is a back vented condenser microphone, the calibration is in error at low frequency. This problem does not arise if the microphone equalization vent is exposed to the sound field. An alternative exciter for the same calibration technique is a cavity [39] designed such that side or back vented microphones can be tested. A phase calibration method that employs a noise source in an anechoic room has been described [40].

Instrumentation. Instrumentation has developed along two paths. The cross spectral formulation of intensity [8] and phase calibration techniques [36, 38] can be used to carry out intensity

measurements (with due regard for limitations and potential errors); two microphones with amplifiers and a two channel Fourier analyzer are needed. Analog instruments that derive and then multiply signals proportional to pressure and particle velocity are traceable [1, 2-4, 7, 41, 42]; but no analog intensity meter has yet enjoyed commercial success. An essentially digital instrument based upon time-domain processing has been described [11, 43] and is available.

APPLICATIONS

Sound Power Determination. A principal application of direct measurement of sound intensity is the determination of sound power radiated by a source. In principle radiated power can be determined in any acoustic environment. In the presence of noise sources outside the hypothetical closed measurement surface the integral of intensity will be zero except for sources within the surface. In practice limitations are dependent upon the choice of surface, number and placement of measurement positions, and accuracy of determination of intensity in the field in question. As yet no definitive guidelines are available for techniques. Measurement positions [32-34, 44, 45] have been discussed, as have limitations of the cross spectral technique [46, 47] and results for practical applications [48-51]. Noise sources in a multi-source environment have been ranked according to sound power output. The sources did not have to be assessed individually or moved into ideal environments; both are impossible on, for example, production line machinery.

Transmission Loss. The transmission loss of some sort of physical barrier separating two acoustic fields is defined as incident sound power divided by transmitted sound power. Intensity measurements are a convenient method for measuring transmitted sound power but are of no use in measuring incident sound power. Such measurements would yield the net of incident and reflected powers.

This problem can be overcome by placing the barrier in a field of known incident intensity such as a window in a wall of a reverberation room [52, 53]. Incident sound power can be deduced from pressure measurements in the reverberation room and confirmed by intensity measurements with the window open (i.e., the barrier removed) to a free field. The method has been applied to an aircraft structure placed in a reverberant field; intensity measurements were made on the interior [54].

Similar measurements have been made using a surface intensity technique [55] in which particle velocity was derived from an accelerometer on the surface under test and a microphone close by. It is assumed that the acoustic particle velocity immediately in front of the vibrating surface is equal to the velocity of the vibrating surface. It is also assumed that the pressure transducer can be placed close enough to the point of velocity measurement such that the effects of the two velocities provides the intensity at that point. More recent work considers a combination of the microphone and surface intensity techniques to distinguish airborne and structure-borne noise paths for aircraft [56]; this work exploits the ability to calculate the radiation efficiency of structures from such measurements. The method has also been applied to measurements in buildings in conjunction with traditional tapping tests [57] for floor isolation. Work continues to be reported [40, 58, 59] that consolidates the basic principles of these transmission loss measurement techniques.

Absorption. The absorption coefficient of a surface is defined as the ratio of absorbed sound power to incident sound power. Intensity measurements can be used to directly determine absorbed sound power. If incident sound can be limited to one-dimensional propagation (as in a standing wave tube), incident and reflected intensities can be separated [60, 61]; the normal incidence absorption coefficient can thus be determined. Alternatively the absorbent surface can be placed in a reverberant room and the incident sound power deduced from pressure measurements similar to those used in transmission loss measurements [41, 62]. However, the latter measurement is not generally satisfactory due to the uncertainty of incident sound power and the

accuracy to which absorbed sound power can be measured for small absorption coefficients. The method is useful for comparative measurements of absorbers in situ in terms of sound power absorbed for a particular source.

Radiation Characteristics. One of the most interesting applications of sound intensity measurement has been in investigations of the nature of noise fields close to sources in terms of energy flow into, out of, and around the source. The information derived can be used to find hot spots of radiation or ranking parts of a source (such as parts of an engine) in order of contribution to the total power radiated [51, 63 64]. This source ranking aspect has been taken further to include a multiple input to output model [65, 66] to relate source contributions to individual intensity measurements.

Packages are available to produce intensity maps of radiating surfaces [11, 67, 68] but can display only one component of intensity. (The intensity in a direction normal to the surface is usually most useful). Other research has sought to display intensity vectors in two and three dimensions from both practical and theoretical standpoints [69-73]. These references illustrate the potential difficulties of measuring fields that are not usually regarded as complex. It is sometimes necessary to resolve near field intensity vectors completely to avoid misleading results. An application of intensity mapping and its interpretation in relation to noise radiated by tires has been described [74-76]. A discussion on intensity measurements in enclosed spaces [41] points out other areas in which intensity measurements can be misleading.

There has been some interest in measuring the surface velocity of vibrating surfaces using the two microphone technique [24, 77, 78]; an advantage is ease of a noncontact measurement. A combination of these measurements and intensity measurements derived from the same data have been used to obtain the radiation efficiency of surfaces in building acoustics [57].

The surface intensity technique has also been investigated for similar surface radiation characterization [78, 80] and has been directly compared with the two microphone method [81, 82]. Errors have been discussed [83].

Transient Noise Sources. The application of the two microphone technique to transient noise sources has been discussed [84, 85]. If the complete transient event is appropriately analyzed, all errors and discussion pertinent to continuous sources also apply in the transient case. Differences generally occur because of the need to capture data lengths too long for most dual channel FFT analyzers; for example, impact machines in a reverberant work space. Another reason for differences is that the time history of intensity might be examined to provide further information about the source [86-88]. Applications of these techniques to punch presses have been discussed [89, 90], as have their applications to tapping measurements on floors [57].

Measurements in Flow. If the medium in which intensity measurements are being made is moving, a number of problems arise [91]. The acoustic equations pertinent to a *nonmoving* medium do not apply to the with flow case. This is over and above other practical problems such as turbulence noise around the transducers. A formulation for intensity measurements in flow has been discussed [91], and a recent paper [92] compared several formulations. Practical measurements of intensity in ducts with flow have been given [93, 94] in which conditions are confined to low Mach numbers so that deviation from the no-flow case is not too great.

INTERPRETATION OF MEASUREMENTS

The interpretation of measurements in complex fields has been greatly helped by visualization techniques [71]. This part of the review is concerned with the problem of confidence in an individual measurement in which the nature of the field at the point of measurement is not known. Many of the inherent errors discussed earlier are dependent upon field type; errors due to finite approximations to pressure and particle velocity and phase mismatch can be very large indeed. Esti-

mations of finite approximation errors in an arbitrary field are extremely difficult; however, the method of Mathur [10] might offer an advantage in this direction.

The difference between the sound pressure level (L_p) and the sound intensity level (L_I) in air at the point of measurement has been proposed as an indicator of potential error in measurement [38, 44, 95, 96] and has been shown to be related to the phase error of the system [97]. If a phase mismatch exists in a system and the two transducers of that system are excited by pressures of common magnitude and phase, a particular L_p and L_I would be registered. (In a system with perfect phase matching an L_I = - dB would be registered.) If the field at a measurement point is such that the true $L_p - L_I$ is the same as in the common mode excitation case, a critical error condition indicating either twice the true intensity or zero intensity will prevail. If the true $L_p - L_I$ is greater than this condition, the error will be greater. In a practical situation only the measured $L_p - L_I$ is available, so some sensible limit on this parameter must be established. Figures for the limit of $L_p - L_I$ quoted are 15 dB [44], 18 dB [55], more involved functions of frequency [68]; the limit has also been said to be instrumentation dependent [38]. $L_p - L_I$ has also been related to the random error [27], which increases with $L_p - L_I$ for a constant coherence and number of averages. It is important for an engineer to know his $L_p - L_I$ limitation if he is to obtain useful and meaningful data.

CONCLUSIONS

The literature relating to sound intensity measurement over the last three years has been reviewed. The advantages of direct measurement of sound intensity are very attractive; research into this subject is increasing. Problems of calibration, standardization and assessment of the magnitude of the error in any arbitrary measurement remain.

The author has witnessed measurements being made in circumstances in which measurement errors would be high, but those making the measurements were completely unaware of the inherent limitations of current intensity measurement techniques and systems. There is an increasingly pressing need to educate engineers to perform intensity measurements properly and to interpret the results if this technique is to be successfully transferred from the laboratory to industry.

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

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CONTINUUM MODELING OF LATTICED STRUCTURES

S. Abrate*

Abstract. Continuum modeling is an efficient method for the analysis of latticed structures. An equivalent continuum model is sought in order to model the overall behavior of a discrete structure. This approach has been applied to several types of structures for many problems, including eigenvalue, transient response, large displacements, buckling, and damping analyses.

A structural system consisting of a very large number of elements arranged in a periodic manner is often called a latticed structure. Such structures have long been studied; accounts of earlier work are available [1, 2]. Applications of such structures were originally limited to the field of civil engineering; more recently, however, the study of large space structures (LSS) has provided impetus for research. LSS are very large structures made of truss members assembled modularly and are intended for deployment in outer space to serve, for example, as antennas or telescopes.

The position, shape, and pointing accuracy of LSS must be accurately controlled. They are very light and have very low natural frequencies. Their response to a given disturbance involves a large number of natural modes that must be precisely determined. This special characteristic of LSS is opposed to civil engineering structures the response of which can be computed by considering a small number of modes.

It is generally accepted that the finite element method can be used to solve most problems involving trusses and frames. However, because latticed structures consist of a large number of elements, modeling them using finite elements is cumbersome and requires a large set of equations. The requirements for computer time and memory space are prohibitive, and, as the number of equations to be solved increases, the numerical accuracy of the solution degenerates. In order to circumvent these difficulties, three methods have been proposed: the substructuring method, the order reduction method, and continuum modeling. With the substructuring method [3, 4] solutions to several structural problems of a smaller size are employed to determine the response of the system. Order reduction methods [5-7] require reduction of the full set of equations obtained after discretization to a smaller set by selection of a number of master degrees of freedom and elimination of unwanted variables. These two approaches require descriptions of individual members and formulation of governing equations for the total assemblage; simplifications in the analysis depend on certain mathematical manipulations of the resulting system of equations.

Latticed structures generally are periodic; that is, they consist of a large number of identical cells joined together and appear globally like a beam, plate, or shell. Because of this periodicity and general appearance, the global behavior of the structure should remain simple even though the arrangements of individual members in a typical cell are complex. In other words it should be possible to consider the structure as a continuum with equivalent properties derived from those of the discrete members. This approach is called continuum modeling [8]. In this article its applications to vibration, structural dynamics, and buckling of latticed structures is reviewed.

PRINCIPLE OF CONTINUUM MODELING

The basic premise of continuum modeling is that the behavior of a discrete structure can be deduced by studying that of a continuous one. Mathematically, a large number of second-order ordinary differential equations are replaced by a smaller number of partial differential equations. For example, the global behavior of the truss shown in the Figure can be predicted by considering an equivalent beam. Analysis of the original structure would require solving the following system of equations:

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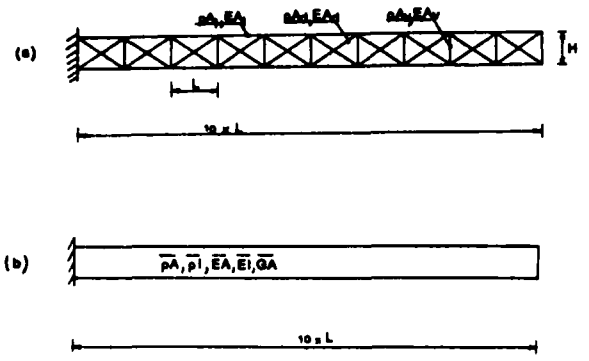
$$M\ddot{X} + KX = F$$

M and K are the mass and stiffness matrices; F represents the applied force and X the vector containing the n degrees of freedom of the structure. This truss can be modeled by a Timoshenko beam model [9] with the following equations of motion:

$$\overline{GA}\ (\psi_{,xx} - w_{,xx}) + \overline{\rho A}\ w_{,tt} = q$$

$$\overline{GA}\ (w_{,x} - \psi\ ) + \overline{EI}\ \psi_{,xx} = \rho I\ \psi_{,tt}$$

$\overline{EI}$, $\overline{GA}$, $\overline{\rho A}$, and $\overline{\rho I}$ are the equivalent rigidities and inertia properties. A simpler Bernoulli-Euler beam model could also be used [9].



Plane Truss (a) original structure; (b) equivalent continuum model

The simplicity of this example shows the advantages of the continuum modeling approach and demonstrates the three basic steps of the method. First, the type of continuum model to be used is selected, as the Timoshenko beam model was chosen in the example. Then the equivalent properties are determined so that the continuum model will behave like the original structure. In the example $\overline{EI}$, $\overline{GA}$, $\overline{\rho A}$, and $\overline{\rho I}$ were determined given the properties of the various elements in the truss. In the third step, the limits of applicability of the continuum models are evaluated. Because many internal details of the structure are neglected in order to determine global behavior, use of these models is limited, and the domain of applicability of each model must be determined.

The various approaches to continuum modeling can be classified according to the type of continuum used in the equivalent model. Classical continuum theories, such as the Bernoulli-Euler beam theory or the classical plate theory, have been used [9-12]. The effects of transverse shear deformation and rotatory inertia are included in models based on the Timoshenko beam theory or the Mindlin plate theory [9, 12-18]; both are improvements over simpler models. The theory of micropolar continua and the couple stress theory, in which local rotations are assumed to be independent from the displacement field, have also been employed [19-23].

Another way to order the various approaches is to group them according to the method used to determine equivalent properties. It has been shown [24] that the equations of motion for a typical cell are written in terms of difference operators and then transformed to differential equations; the equations of motion of the continuum model and explicit expressions for the equivalent properties are given simultaneously. With one approach [17, 18, 20, 21] the kinetic energy and the strain energy of a typical cell are first written in terms of nodal displacements. A Taylor series expansion is used to relate the discrete variables to the continuous displacement field. The equations of motion of the continuum model are then obtained by applying the principle of virtual work. General methods [25, 26] are used to study heterogeneous periodic structures by a method of homogenization using multiple scale asymptotic expansions. These methods have been applied to composite materials and to structures of the type considered here [27, 28].

The three approaches described above for deriving a continuum model require extensive algebraic manipulations; the entire derivation must be repeated for every type of basic cell. However, the explicit expressions obtained to calculate the equivalent properties of a structure provide valuable insight into its behavior.

With one method proposed [9] the equivalent model is assumed to be a given continuum -- a Timoshenko beam, for example -- and the equivalent properties are determined numerically. A finite element model of a single

typical cell is subjected to a number of loadings, and the equivalent properties are determined from the results of these tests, much like material properties are determined experimentally. The lengthy derivations needed with other methods are thus avoided.

The discrete structure has been considered as the sum of several arrays of parallel elements [13, 14]. Each array is assumed to provide reinforcement in one direction; the volume must be averaged and proper tensor transformation must be made to obtain the properties of an equivalent three-dimensional orthotropic material. This equivalent material model is used with a plate theory to obtain an equivalent continuum model.

APPLICATIONS TO STRUCTURAL DYNAMICS

Continuum models are used to predict natural frequencies and mode shapes and to calculate transient responses. Beam-like and plate-like latticed structures have received the most attention because they are the basic building blocks of LSS. In-plane and transverse vibration of grids have also been studied.

For beam-like structures the Bernoulli-Euler and Timoshenko beam models have been used [9, 10, 15-18], as have micropolar beam models [20, 21]. Continuum models can predict the lower natural frequencies of a structure; the number of frequencies determined accurately depends on boundary conditions, the number of cells in the structure, and the model employed. For a given structure the Timoshenko beam model allows the prediction of more natural frequencies and mode shapes, in agreement with the direct finite element solution, than does the Bernoulli-Euler beam model [9, 12, 15, 17, 18]. For beam-like structures with rigid joints micropolar beam models allow nodal rotations to be predicted more accurately [20, 21]. However, with the Timoshenko beam model, the natural frequencies corresponding to overall bending motion are determined with the same degree of accuracy and also retain a simpler formulation [12].

Harmonic wave propagation analysis has been used to evaluate several continuum models [12, 15]. Wave propagation in periodic structures differs from that in continua because free harmonic waves propagate only in certain frequency ranges called passbands. If a typical cell is considered, the behavior of a discrete structure can be compared to that of the continuum model. For long wavelengths the dispersion curves of the discrete structure are approximated by those of its equivalent continuum model. These models satisfactorily represent the overall behavior of a structure for long wavelengths compared to the length of a typical cell; therefore, limits can be set in terms of the ratio of the wavelength of the disturbance to the cell length. Wave propagation analysis also allows verification that some important deformation mode has not been missed in the development of the continuum model [15].

Spatial truss beams with rectangular cross sections exhibit a deformation similar to that produced by a bimoment in thin-walled beams [21]. Plots of dispersion curves for the original structure show that this deformation mode must be accounted for [12]. The use of Bernoulli-Euler beam models is limited to long wavelengths; the Timoshenko beam model is valid for shorter wavelengths and gives results identical to those obtained with the more involved micropolar beam theory [12]. Wave propagation in periodic structures has also been considered [29, 30].

Static and transient response analyses, including geometrically nonlinear effects, have been presented [10]. Beam-like trusses undergoing large deflections were studied using matrix methods; equivalent continuum models were based on the properties of a typical substructure of the truss. Solutions obtained from both methods were compared for a number of examples.

For plate-like latticed structures, continuum models accounting for transverse shear deformation and rotatory inertia have been applied successfully [9, 13, 14, 17]. As was the case with beams equivalent models that do not account for the two effects can sometimes be employed when the wavelength of the disturbance is very large in

comparison to the length of a basic cell.

In-plane vibrations of grids have been studied using continuum models based on higher order continuum theories [19, 22]; the nodal rotations were kept independent of the field displacements in the equivalent models. Transverse vibrations of grids have been analyzed [31]; plates reinforced by a network of parallel beams have been shown to be equivalent to a homogeneous elastic plate [27].

BUCKLING

Planar trusses have been studied [32]; for several types of truss the critical buckling loads were given in terms of equivalent bending rigidities. The analogy between results obtained for the discrete structure and those for a continuous beam was brought out, but a continuum model was not used.

The buckling of a plane structure composed of beams and columns has been studied [33] using an equivalent beam-column model. The stability of beam-like lattice trusses has been analyzed [34]; the equivalent continuum model was derived with a method already used [17]. The subject of buckling of periodic lattice structures has also been covered [35, 36].

Analyses have been presented [37, 38] for determining the buckling load of triangular lattice columns with local and overall imperfections. The sensitivity to local geometric imperfections in the flanges of elastic plastic truss columns has been studied [39]. The homogenization method [28] has been applied to the buckling of plates reinforced either by inclusions or by beams. Determination of critical loads was reduced to that of a homogeneous plate.

DAMPING

Passive damping in LSS is recognized as necessary in order to assure the stability of the control system and to limit the number of sensors and actuators necessary for this control system [40]. It is thought that damping factors of one to ten percent are achievable and that, with special materials yet to be designed, damping levels will be an inherent manufacturing specification [41].

Sources of damping are many: structural damping, joint friction, and large scatter in experimental data have been observed [42]. The mathematical treatment of damping in structural analysis has been reviewed [42, 43]. Damping models generally are of the linear-viscous type, in which the equations of motion are:

$$M\ddot{x} + D\dot{x} + Kx = f(t)$$

M, D, and K are the mass, damping, and stiffness matrices respectively, x contains the generalized coordinate, and f the generalized inputs. The most common procedure is to assume that D is a linear combination of M and K in order to assure the simultaneous diagonalization of the three matrices. A discussion of the shortcomings of this approach is available [41]. Hysteretic damping models have also been used to study the steady-state response of structures for which damping effects are frequency independent [42, 43].

With both types of models damping is prescribed at the structural level on the basis of experience, similar structures, or direct test results. Because experience is not available and ground testing is generally not feasible [44] for LSS, damping must be prescribed at the element level. The introduction of damping in the structural model, even in its simplest form, emphasizes the need for simple models.

Internal damping in beam-like trusses has been studied [45]. Each member was assumed to behave either as a Kelvin-Voigt solid, a standard linear solid, or a hysteretic material. An equivalent Timoshenko beam model that included damping effects was developed; results for steady-state and transient response analyses were compared with solutions for the equation of motion of the original discrete structure.

CONCLUSION

Continuum modeling of latticed structures has been shown to be very effi-

cient for a wide range of applications. The use of simple models renders the task of analyzing the structure easier; in many cases it is the only approach possible, because, for very large structures, the full-blown finite element model would be intractable. Buckling, eigenvalue, transient response, large displacements, and damped vibrations problems of latticed structures can be analyzed using the continuum modeling method. This approach is thus of interest to those who need efficient and accurate analytical methods for structural analysis and design, active control system design, or parameter identification of LSS.

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BOOK REVIEWS

WIND EFFECTS ON CIVIL ENGINEERING STRUCTURES

V. Kolousek, M. Pirner, O. Fischer, and J. Náprstek
Elsevier Scientific Publishing
Amsterdam - Oxford - New York - Tokyo
1984, 684 pp

This book is a translation of a revised, enlarged, and updated text of the Czech edition published in 1977 by Professor Kolousek and three of his students. The book outlines general trends in the field of wind effects on civil engineering structures and presents results from literature and their own studies. The book consists of 13 chapters, a list of 782 references, and a series of examples.

Chapter 1 presents a general discussion of wind characteristics and dynamic effects on structures. The following are characterized: wind speed, aerodynamic coefficients, response of structures to wind loads and standards used to study wind loads. This chapter contains a summary of problems in the field.

Chapter 2 deals with the response of structures to deterministic and stochastic loads. Methods for calculating natural frequencies and mode shapes of different structural components are presented.

Chapter 3 focuses on scaled models. Similitude requirements, wind tunnels, aerodynamic models, and experimental techniques are discussed.

Chapters 4, 5, and 6 are short chapters on various subjects. Chapter 4 discusses the measurement of structural displacement, velocity, stress, and acceleration on full-scale structures such as tall buildings, masts, towers, and stacks. Chapter 5 considers different types of failure: latent failure, local failure, and total failure. Chapter 6 defines criteria for estimating wind effects.

The next seven chapters treat various civil engineering structures using the principles presented in Chapters 1 to 6: tall buildings, guyed masts, towers and stacks, cooling towers, bridges, roofs, and permeable structures. The behavior of these structures is analyzed. Emphasis is given to various interesting subject areas,for example, aerodynamic instability of bridges, dynamic response of periodic tall buildings, effects of guy cable on masts, and aeroelastic instability of cooling towers.

This book covers a wide variety of civil engineering structures subjected to wind loads and contains an extensive list of references. It will be useful to researchers in the area of fluid-structure interaction and designers in wind engineering. The problems presented in the book are subjects of current research in different parts of the world. The authors have included recently published results and data however some important results are not given, because of rapid developments in some subject areas in this field.

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SEISMIC MOUNTINGS FOR VIBRATION ISOLATION

J.A. Macinante
Wiley-Interscience, John Wiley & Sons
New York, 1984, 279 pp, $39.00

Occasionally, a technical book is published that serves to bridge the gap between engineering theory and practical design. Seismic Mountings for Vibration Isolation is such a book. Drawn from the author's experience in vibration isolation over more than three decades, this book offers that rare combination of rigorous treatment of a subject with special emphasis on the physical significance and practical constraints of the engineering problems at hand. Mathematical

derivations are held to a minimum; instead, the author cites appropriate references where such details can be obtained. In spite of the omission of extensive mathematical treatment, the book is not oversimplified. It deals with the design of isolators in a way that is consistent with vibration theory and, clearly establishes the physical basis for vibration isolation.

Extensive published material exists on vibration isolation and damping, yet these areas are among the least understood in engineering. On the surface, the theories involved appear to be simple. Perhaps this is why the practical difficulties associated with properly applying isolation and damping are often ignored. As Macinante points out in the Preface, it would seem that mountings are still being designed on the assumption that all will be well if the natural frequency of the mounting is appreciably lower than the frequency of the vibration to be isolated. Yet, a mounting so designed for a vibrating machine might be useless if the response of the supporting floor is ignored; or a mounting for sensitive equipment might not do its job if the response of the critical part of the equipment is ignored. In looking critically at these and similar considerations, Macinante is concerned with the "practice" of vibration control.

The book contains nine chapters. Chapter 1 introduces the reader to vibration in terms of everyday human experience. Natural and man-made sources of vibration are described. Vibration is characterized as both useful and harmful; a rationale for the control of unwanted vibration is provided; an overview of seismic mountings is given. Chapter 2 deals clearly and concisely with basic vibration terminology. Equipment and techniques for vibration measurement and analysis are also summarized. In effect, the first two chapters provide an introduction to vibration that is both informative and entertaining.

In Chapter 3 the author cleverly introduces the reader to the basic principles of vibration isolation. These principles are revealed in terms of those options available for the control of unwanted vibration. Action at the source, such as dynamic balancing, selective siting or seismic mounting, can be the first consideration. A second possibility is the modification of the transmission path by such mechanisms as damping or the use of a dynamic absorber. The author's third option, action at the receiver, can involve a wise choice for equipment location or seismic mounting of either the equipment or the whole building. Choices under the three options are often illustrated by realistic examples. Finally, expanding on an idea offered by Eshleman in 1973, the author suggests an insurance policy for successful vibration control.

In Chapter 4, Macinante discusses vibration criteria in terms of equipment performance, human response, and structural integrity. The chapter provides guidance and background for those who must decide whether vibration control is a problem and, if so, what should be done about it. Chapter 5 provides an excellent overview of seismic mounting technology, including types of mountings, mounting arrangements, and selection of materials. In addition to technical considerations, the author provides a design guide on some important practical matters. A section in testing to assure acceptable performance of seismic mountings concludes the chapter.

Along with Chapter 5, Chapters 6 through 9 are the heart of the book. The design of seismic mountings is examined in terms of the practical application of meaningful and relevant theory. Chapter 6 covers design models and their usefulness, limitations, and practical applications. Chapter 7 deals with free vibration and the various modes that involve horizontal, vertical, roll, pitch, and yaw motions. Rotational modes and coupled modes are also considered. Chapter 8 covers the design of mountings for machinery on suspended floors; Chapter 9 deals with mountings for sensitive equipment. In both chapters Macinante opts for design data based on two-mass models and, in each case, includes appropriate and useful material on the practical application of the design data.

Throughout the book, examples are given to illustrate both good and bad design practice. Tables and charts are

used to good advantage. Each chapter is introduced by a quotation that is skillfully incorporated into the subject. I highly recommend the book to anyone concerned with problems in vibration control. Whether used as a textbook or a handbook, it is invaluable in clarifying many of the misconceptions surrounding isolation and damping.

H.C. Pusey
2402 James Madison Highway
Haymarket, VA 22069

FRACTURE OF ENGINEERING BRITTLE MATERIALS

A.de S. Jayatilaka
Applied Science Publishers, Ltd.,
London, 1979, 378 pp

The book is an ambitious undertaking. The author sets out to describe the relationships between material behavior and the external environment to which a structure made from the material is subjected. After a brief introduction he presents the principal equations of the theory of elasticity. Within a few pages he introduces linear, elastic fracture mechanics and presents the Westergaard and Mushkellishvilli analytical methods. Considerable background on behalf of the student is presumed. In the third chapter the concepts of a criterion of failure are clearly stated and elaborated. The chapter contains a discussion of fracture-influencing factors and modifications necessary to include limited or substantial plastic flow in basic equations. An excellent summary of failure criteria concludes the chapter. It is in fact reason enough for the serious student to purchase the book.

Chapter 4 deals with complications of a multiaxial stress state and revisions to both deterministic failure models and fracture mechanics models. Statistical approaches to brittle fracture are also described. Traditional statistical models for mechanical systems are presented and explained. The approach of statistical vs deterministic fracture models is elaborated. Chapter six describes experimental testing techniques for both deterministic and statistical failure models.

From this point the book deals with the brittle fracture characteristics of specific types of material. Chapter 7 is concerned with composite materials; several topics not found elsewhere in similar books are presented. It is an interesting and well presented treatment. Chapter 8 deals with the brittle fracture characteristics of concrete. It is followed by a similar treatment of engineering ceramics in Chapter 9.

Overall the book should prove to be an excellent text for courses in brittle fracture at the master's level. It should be useful in both civil and mechanical engineering curricula.

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SHORT COURSES

FEBRUARY

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: February 4-8, 1985
Place: Santa Barbara, California
Dates: March 11-13, 1985
Place: Washington, D.C.
Dates: May 6-10, 1985
Place: Boston, Massachusetts
Dates: June 3-7, 1985
Place: Santa Barbara, California
Dates: August 26-30, 1985
Place: Santa Barbara, California

Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos Strseet, Santa Barbara, CA 93105 - (805) 682-7171.

MACHINERY INSTRUMENTATION

Dates: February 5-7, 1985
Place: Anchorage, Alaska
Dates: February 19-21, 1985
Place: Houston, Texas
Dates: March 12-14, 1985
Place: Edmonton, Alberta, Canada
Dates: April 16-18, 1985
Place: Philadelphia, Pennsylvania
Dates: May 14-16, 1985
Place: San Francisco, California
Dates: June 25-27, 1985
Place: Denver, Colorado
Dates: November 12-14, 1985
Place: Calgary, Alberta, Canada

Objective: This seminar provides an in-depth examination of vibration measurement and machinery information systems as well as an introduction to diagnostic instrumentation. The three-day seminar is designed for mechanical, instrumentation, and operations personnel who require a general knowledge of machinery information systems. The seminar is a recommended prerequisite for the Machinery Instrumentation and Diagnostics Seminar and the Mechanical Engineering Seminar.

Contact: Customer Information Center, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-3611, Ext. 9243.

MACHINERY VIBRATION ANALYSIS

Dates: February 19-22, 1985
Place: Tempe, Arizona
Dates: August 13-16, 1985
Place: Nashville, Tennessee
Dates: Oct. 29 - Nov. 1, 1985
Place: Oak Brook, Illinois

Objective: This course emphasizes the role of vibrations in mechanical equipment instrumentation for vibration measurement, techniques for vibration analysis and control, and vibration correction and criteria. Examples and case histories from actual vibration problems in the petroleum, process, chemical, power, paper, and pharmaceutical industries are used to illustrate techniques. Participants have the opportunity to become familiar with these techniques during the workshops. Lecture topics include: spectrum, time domain, modal, and orbital analysis; determination of natural frequency, resonance, and critical speed; vibration analysis of specific mechanical components, equipment, and equipment trains; identification of machine forces and frequencies; basic rotor dynamics including fluid-film bearing characteristics, instabilities, and response to mass unbalance; vibration correction including balancing; vibration control including isolation and damping of installed equipment; selection and use of instrumentation; equipment evaluation techniques; shop testing; and plant predictive and preventive maintenance. This course will be of interest to plant engineers and tech-

nicians who must identify and correct faults in machinery.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254

MARCH

MECHANICAL ENGINEERING
Dates: March 4-8, 1985
Place: Carson City, Nevada
Dates: August 12-16, 1985
Place Carson City, Nevada
Objective: This course is designed for mechanical, maintenance, and machinery engineers who are involved in the design, acceptance testing, and operation of rotating machinery. The seminar emphasizes the mechanisms behind various machinery malfunctions. Other topics include data for identifying problems and suggested methods of correction.

Contact: Customer Information Center, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-3611, Ext. 9243.

PENETRATION MECHANICS
Dates: March 18-22, 1985
Place: San Antonio, Texas
Objective: This course presents the fundamental principles of penetration mechanics and their application to various solution techniques in different impact regimes. Analytical, numerical, and experimental approaches to penetration and perforation problems will be covered. Major topic headings of the course are: fundamental relationships, material considerations, penetration of semi-infinite targets, perforation of thin targets, penetration/perforation of thick targets, hydrocode solution techniques, experimental techniques. Discussions will include such topics as fragment or projectile breakup, obliquity, yaw, shape effects, and richochet. Shock propagation, failure mechanisms and modeling, constitutive relations, and equation-of-state will be presented in the context of penetration mechanics. Developed fundamental relationships will be applied in the following areas: hypervelocity impact, long rod penetration; spaced and composite armors, explosive initiation, hydrodynamic ram, fragment containment, earth penetration, crater/hole size, spallation, shaped charge penetration.

Contact: Ms. Deborah J. Stowitts, Southwest Research Institute, 6220 Culebra Road, San Antonio, TX 78284 -(512) 684-5111, Ext. 2046

MACHINERY INSTRUMENTATION AND DIAGNOSTICS
Dates: March 19-22, 1985
Place: Orlando, Florida
Dates: March 26-29, 1985
Place: Syracuse, New York
Dates: May 6-10, 1985
Place: Carson, Nevada
Dates: June 4-7, 1985
Place: Pittsburgh, Pennsylvania
Dates: July 15-19, 1985
Place: Carson City, Nevada
Dates: September 10-13, 1985
Place: New Orleans, Louisiana
Dates: September 24-27, 1985
Place: Anaheim, California
Dates: October 8-11, 1985
Place: Philadelphia, Pennsylvania
Dates: October 21-25, 1985
Place: Carson City, Nevada
Dates: November 5-8, 1985
Place: Boston, Massachusetts
Dates: December 3-6, 1985
Place: Houston, Texas
Objective: This course is designed for industry personnel who are involved in machinery analysis programs. Seminar topics include a review of transducers and monitoring systems, machinery malfunction diagnosis, data acquisition and reduction instruments, and the application of relative and seismic transducers to various types of rotating machinery.

Contact: Customer Information Center, Bently Nevada Corporation, P.O. Box 157, Minden, NV 89423 - (702) 782-3611, Ext. 9242.

VIBRATION CONTROL
Dates: March 25-29, 1985
Place: Manassas, Virginia

Dates: June 3-7, 1985
Place: San Diego, California
Objective: This vibration control course will include all aspects of vibration control except alignment and balancing. (These topics are covered in separate Institute courses.) Specific topics include active and passive isolation, damping, tuning, reduction of excitation, dynamic absorbers, and auxiliary mass dampers. The general features of commercially available isolation and damping hardware will be summarized. Application of the finite element method to predicting the response of structures will be presented; such predictions are used to minimize structural vibrations, during the engineering design process. Lumped mass-spring-damper modeling will be used to describe the translational vibration behavior of packages and machines. Measurement and analysis of vibration responses of machines and structures are included in the course. The course emphasizes the practical aspects of vibration control. Appropriate case histories will be presented for both isolation and damping.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254

MODAL TESTING OF MACHINES AND STRUCTURES
Dates: March 26-29, 1985
Place: Manassas, Virginia
Dates: August 13-16, 1985
Place: Nashville, Tennessee
Objective: Vibration testing and analysis associated with machines and structures will be discussed in detail. Practical examples will be given to illustrate important concepts. Theory and test philosophy of modal techniques, methods for mobility measurements, methods for analyzing mobility data, mathematical modeling from mobility data, and applications of modal test results will be presented.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

APRIL

MACHINERY RISK MANAGEMENT
Dates: April 15-17, 1985
Place: Carson City, Nevada
Objective: This course is a sequel to a risk seminar presented two years ago in Carson City, Nevada. It is designed to update insurance/risk managers on recent developments in predictive maintenance and diagnostic programs for rotating machinery.

Contact: Customer Information Center, Bently Nevada Corporation, P. O. Box 157, Minden, NV 89423 - (702) 782-3611, Ext. 9243.

MAY

ROTOR DYNAMICS
Dates: May 6-10, 1985
Place: Syria, Virginia
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254

OCTOBER

VIBRATIONS OF RECIPROCATING MACHINERY
Dates: Oct. 29 - Nov. 1, 1985
Place: Oak Brook, Illinois
Objective: This course on vibrations of reciprocating machinery includes piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory --including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic resonance phenomena and digital acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compressors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be emphasized. Case histories and examples will be presented to illustrate techniques.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

2nd NATIONAL TAILORING CONFERENCE
June 24-26, 1985
Leesburg, Virginia

The general theme of the Second National Tailoring Conference is "Tailoring of Environmental Standards in the Control of Contractual Requirements," and will again be held at the Xerox International Center for Training and Management Development, Leesburg, Virginia, from June 24-26, 1985.

The conference and workshop will be sponsored by the Institute of Environmental Sciences in cooperation with the Department of Defense. Kurt Greene of the Defense Material Standards and Specifications Office (DMSSO) will serve as General Chairman and Robert Hancock, IES Technical Director for the Product Reliability Division, (Vought Corporation) as Technical Chairman. The ultimate goal of this conference and workshop is to establish guidance material for the formation and implementation of tailoring requirements in the areas of: Management and Planning; Design and Analysis; Test and Verification; and Education and Training.

Registration for this conference is limited to 300 and the fee will include full room and board, conference fees and proceedings.

For further information contact: IES Technical Vice President, Joseph Popolo, Grumman Aerospace, (516) 575-5084, or the IES National Office, (312) 255-1561.

STRUCTURES AND MATERIALS PANEL OF THE NATO ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT SPRING '85 MEETING
April 21-26, 1985
San Antonio, Texas

The Structures and Materials Panel (SMP) of the NATO Advisory Group for Aeronautical Research and Development (AGARD) will hold its Spring '85 meeting during the week of 21-26 April in San Antonio, Texas. The meeting will include UNCLASSIFIED technical specialists' meetings on two subjects of great interest to the logistics community:

Damage Tolerance Concepts for Critical Engine Components

- Damage Tolerance
- Durability
- NDI
- Thermal Analyses
- Stress Analyses
- Fracture Mechanics
- New Alloys
- Test Methods
- Case Histories

Aircraft Gear and Bearing Tribological Systems

- Gears
- Gear Boxes
- Bearings
- Secondary Power Systems
- Gear Materials
- Laboratory Simulation
- Usage Monitoring
- Production Weaknesses
- Lubricants
- Wear

In both of these meetings leading researchers and managers from North America and Europe will be presenting results and prospects from their research and development programs.

Invitation to AGARD meetings is limited to citizens of the NATO countries and is by invitation only. If you or members of your organization wish to attend, you should send the following information: Name, Title, Organization, Department, Street Address, Phone Number, Social Security Number, and Citizenship Status.

For further information contact: Dr. James J. Olsen, AFWAL/FIB, Wright-Patterson AFB, OH 45433 - (513) 255-5723, (AV) 785-5723.

STANDARDS NEWS

Avril Brenig, Standards Manager

ASA Standards Secretariat, Acoustical Society of America
335 East 45 Street, New York, New York 10017

William A. Yost

Parmly Hearing Institute, Loyola University of Chicago, 6525 North Sheridan Road, Chicago, Illinois 60626

American National Standards (ANSI Standards) in the area of physical acoustics, bioacoustics, mechanical shock and vibration, and noise are published by the Acoustical Society of America (ASA). In addition to these standards, other Acoustical Society standards a Catalog of Acoustical Standards—ASA Cataog 4-1983, and an Index to Noise Standards–ASA STDS. Index 2-1980 (national and international) are available from the Standards Secretariat of the Acoustical Society. To obtain a current list of standards available from the Acoustical Society, write to Avril Brenig, at the above address. Telephone number: (212) 661-9404.

Calendar

The Fall meetings of the ASA standards committees will be held 8–11 October in Minneapolis, Minnesota.

1984 October 08, ASA Committee on Standards, 7:30 p.m., the Leamington Hotel, Minneapolis, Minnesota. Meeting of the Committee that directs the ASA Standards Program.

1984 October 10, Accredited Standards Committee S2 on Mechanical Shock and Vibration (also Technical Advisory Group for ISO/TC/108 and IEC/SC/50A), 2:00 p.m., The Leamington Hotel, Minneapolis, Minnesota. Review of international and S12 activities and planning for future meetings.

1984 October 11, Accredited Standards Committee S12 on Noise (also Technical Advisory Group for ISO/TC43/SC1), 9:30 a.m., The Leamington Hotel, Minneapolis, Minnesota. Review of international and S12 activities and planning for future meetings.

1984 October 11, Accredited Standards Committees S1 (Acoustics) and S3 (Bioacoustics) (also Technical Advisory Group for ISO/TC/43, IEC/TC/29, and IEC/TC108/SC4) at 1:30 p.m. at the Leamington Hotel, Minneapolis, Minnesota. The S3 meeting will be held first. Review of S1, S3, and international standards activities and planning for future meetings.

Standards News from the United States

The following news items have been received since the last issue of Standards News:

ASACOS nominates officers

At the Spring meeting of the Acoustical Society of America Committee on Standards (ASACOS) the Nomination Committee chaired by T. F. W. Embleton submitted the following list of officers. The list was approved by ASACOS for submittal to the appropriate Accredited Standards Committees for confirming votes.

Accredited Standards Committees:

S1: T. Embleton, continuing as Chairman (1982–85)
D. Johnson, continuing as Vice Chairman (1982–85)
T. Embleton, as ASA representative (1982–85)
D. Johnson, as alternate ASA representative (1982–85)
S. Ehrlich was appointed as individual expert Nov. 1983 subject to approval by S1
Reappoint all individual experts for 1984–85.

S2: P. Maedel, continuing as Chairman (1983–86)
S. Feldman, continuing as Vice Chairman (1983–86)
P. Maedel, as ASA representative (1983–86)
S. Feldman, as alternate ASA representative (1983–86)
P. Baade was appointed as individual expert Nov. 1983 subject to approval by S2
Reappoint all individual experts for 1984–85.

S3: L. Wilbur, Chairman (1984–87), ex Vice Chair
H. Silbiger, Vice Chairman (1984–87)
W. Yost, as ASA representative (1984–85), ex chair
L. Wilbur, continuing as alternate ASA representative (1984–85)
Reappoint all individual experts for 1984–85
W. Yost, add as individual expert for 1984–85.

S12: K. Eldred, continuing as Chairman (1982–85)
W. Melnick, continuing as Chairman (1982–85)
K. Eldred, as ASA representative (1982–85)
W. Melnick, as alternate ASA representative (1982–85)
P. Baade and R. Bartheld were appointed as individual experts Nov. 1983 subject to approval by S12
Reappoint all individual experts for 1984–85
R. Young, add as individual expert for 1984–85.

ANSI Progress Report issued

ANSI has just issued its 1984 Progress Report, which provides a profile of the Institute—its functions, organization, financing, membership, and staff. Highlighted in the 24-page booklet are ANSI accomplishments in the past year.

1983 was very productive. ANSI extended its planning and coordination services to the emerging technologies of industrial automation, telecommunications, and fiber optics. Actions on American National Standards increased 60%. Several cooperative programs were initiated, some of them with Japanese standards interests, to expand trade opportunities and help reduce technical barriers. Participation in international standardization and cooperation with government continued at high levels.

Details are provided in the Progress Report. Copies have been mailed to ANSI's company, organizational, and governmental member contacts. Single copies are available without charge on request to the Institute's Communications Department.

Programs and Seminars from NBS

New computer programs for nonlinear least squares. Statisticians and data analysts will be interested in STARPAC (the Standards Time Series and Regression Package), a library of FORTRAN subroutines for statistical data

 0001-4966/84/090989-02$00.80

analysis developed by the NBS Statistical Engineering Division. The first installment of STARPAC consists of state-of-the-art algorithms for unconstrained nonlinear least squares. These subroutines provide a number of features designed to facilitate their use, including carefully designed user documentation, several levels of user control of the computations, and extensive error handling facilities.

NBS issues primer on measuring 60-Hz fields. Laboratories studying the biological effects of high voltage transmission lines with 60-Hz alternating current lab simulations of electric and magnetic fields should find a new NBS report useful. Prepared by the bureau's Center for Electronics and Electrical Engineering, the report is intended as *a primer to help in the measurement of several important electrical parameters* such as electric field strength and magnetic induction. The report discusses devices for generating electric and magnetic fields similar to those found near transmission lines. Also included are several sections on how to control variables that can affect the accurate measurement of electric fields. The report shows how fairly simple instruments can be used to characterize the electric and magnetic fields used in animal exposure studies. *Electrical Parameters in 60-Hz Biological Exposure Systems and Their Measurement: A Primer* (TN1191) is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, for $2.25 prepaid. Use stock no. 003-003-02581-1.

Frequency measurement seminar. This seminar is intended for engineers and lab technicians involved in making frequency calibrations. The course will be taught on a practical level with special emphasis on the new NBS Frequency Measurement Service. This service is a turn-key system installed at the user's site which provides high-accuracy frequency measurements traceable to NBS. Topics to be covered in the seminar include *calibration of crystal oscillators, using frequency counters, choosing a frequency calibration source, care and use of frequency sources, using Loran-C, VLF, and WWVB for frequency calibrations, and the new frequency measurement service.* Registration fee is $400.00 and registration deadline is October 12. Sponsored by NBS. Contact: Mike Lombardi, Division 524, National Bureau of Standards, Boulder, CO 80303: (303) 497-3212.

Metric Council seeks consumer advice

Are you a consumer professional with an interest in the impact of packaging products in metric units? If so, the American National Metric Council would like to hear from you.

It is looking for professionals to serve on its consumer advisory group and react to the effect of weighing, packaging, and labeling consumer products in metric. For additional information, contact: Cheryl Cummins, vice-president, American National Metric Council, 5410 Grosvenor Lane, Bethesda, MD 20814: (301) 530-8333.

ANSI founded the American National Metric Council in 1973 to help assist the private sector in coordination and planning for conversion to the metric system of measurement. In 1976 the Council became an independent body and an organizational member of ANSI.

Scopes of ASTM Committees E-33 on Environmental Acoustics

Scope of ASTM Committee E-33 on Environmental Acoustics: The development of standards on the characteristics and performance of materials, products, systems and services relating to the acoustical environment and the promotion of related knowledge. C. W. Rodman, Chairman; C. W. Sherry, Vice Chairman; S. M. Brown, Secretary; Ron Moulder, Membership Secretary.

Task Groups of Subcommittee 1 on Sound Absorbing Materials, K. W. Walker, Chairman; A. J. Campanella, Vice Chairman; J. W. Kopec, Secretary.

Scope: The development of test methods and specifications for the sound absorption and other physical properties of materials, products and systems as designed or used for the absorption of airborne sound.

Task Groups of Subcommittee 2 on Open Plan Spaces, R. K. Herbert, Chairman; M. A. Lang, Vice Chairman; F. A. Barge, Secretary.

Scope: The development of test methods and practices relating to materials, products, and systems used for the control of acoustics in open plan spaces such as offices, schools, etc.

Task Groups of Subcommittee 3 on Sound Transmission, A. C. C. Warnock, Chairman; J. W. Loney, Vice Chairman; J. C. Haines, Secretary.

Scope: The development of standards dealing with the sound transmission characteristics and performance of materials, products, and systems relating to the acoustical environment and the response thereto.

Task Groups of Subcommittee 4 on Application of Acoustical Materials and Systems, R. J. Peppin, Chairman; D. A. Harris, Vice Chairman; E. M. Clark, Secretary.

Scope: The development of standards for installation and use of acoustical materials, products, and systems that will lead to predictable performance in buildings.

Task Groups of Subcommittee 5 on Research, M. A. Lang, Chairman; C. I. Holmer, Vice Chairman; R. J. Peppin, Secretary.

Scope: To develop test procedures common to two or more test standards; to establish guidelines for the metrication of E-33 standards; to coordinate research projects aimed at improving E-33 test procedures, and to promote publication of test and research information developed by E-33.

Task Groups of Subcommittee 6 on International Stand[illegible]s, R. M. Guernsey, Chairman; S. L. Yaniv, Vice Chairman; Ron Moulder, Secretary.

This subcommittee is the U. S. Technical Advisory Group for ISO/TC 43/SC 2 on Building Acoustics. Its scope is: To review ISO/TC 43/SC 2 documents, attend meetings, provide U. S. technical advice, and to submit voting recommendations for the U. S. position to ANSI.

Task Groups of Subcommittee 7 on Definition and Editorial, E. M. Clark, Chairman; R. A. Putnam, Vice Chairman; Secretary to be appointed.

Scope: To promote the use of consistent language in the several standards under the jurisdiction of Committee E-33.

Task Groups of Subcommittee 8 on *Mechanical and Electrical System* Noise, H. F. Kingsbury, Chairman; R. J. Peppin, Vice Chairman; W. J. Hansen, Secretary.

Scope: includes all the noise produced by all mechanical and electrical equipment on the building site at completion but prior to occupancy.

Standards News from Abroad

The following news item has been received since the last issue of Standards News:

IEC report issued on measurement of ultrasonic magnetostrictive transducers

The International Electrotechnical Commission (IEC) has issued a report specifying the essential characteristics and the preferred methods of measurement for evaluating the performance of transducers.

The report applies to magnetostrictive transducers, of both laminated metal and ferrite types, designed for producing sonic or ultrasonic acoustic power in liquid or solid media, and for different kinds of ultrasonic processing such as cutting, welding, chemical processing, etc.

The transducers covered by the report may be sonic or ultrasonic, operate at resonance frequency, and are supplied from electric power generators.

The report also applies, with some modifications, to special transducers, for example, those designed for application to molten metals, etc. Only transducers with a single working frequency of resonance are considered while those for information carrying signals are excluded.

Standards approved and published by ANSI

The following standards were approved and published by the ASA:

S12.6-1984 "Real-Ear Attenuation of Hearing Protectors, Method for the Measurement of the (revision and designation of ANSI (S3.19-1974)"

S12.7-1984 "Impulse Noise, Methods for the measurement of"

S1.40-1984 "Specification for Acoustical Calibrations"

S2.20-1983 (SAS Catalog No. 20) "American National Standard Estimating Airblast Characteristics for Single Point Explosions in Air, with a Guide to Evolution of Atmospheric Propagation and Effects"

S2.45-1983 "Electrodynamic Test Equipment for Generating Vibration—Methods of Describing the Characteristics of the Equipment (counterpart to ISO 5344-1980)"

S2.58-1983 "Auxiliary Tables for Vibrations Generators—Methods of Describing Equipment Characteristics (counterpart to ISO 6070-1981)"

S3.29-1983 "Guide to the Evaluation of Human Exposure to Vibration in Buildings"

S12.1-1983 (ASA Catalog No. 49) "American National Standard Guidelines for the Preparation of Standard Procedures to Determine the Noise Emission from Sources"

The above standards are available from the Standards Secretariat at the following address: AIP Publication Sales, Department STD, 335 East 45th Street, New York, NY 10017. (A 20% discount is available to individual and sustaining members of the Society.)

International documents on acoustics received in the United States

The documents listed below have been received by the Standards Secretariat of the Society and have been announced to S1, S2, S3, or S12. The document number is listed to the left of each document and the Accredited Standards Committee to which the document was announced is listed in parentheses below the document number. Further information on each document can be obtained from the Standards Secretariat.

The following documents have been received from ISO for vote:

ISO/TC 43

ISO/DIS 1680/1.2 (S12) Acoustics—test code for the measurement of airborne noise emitted by rotating electrical machinery—Part 1: Engineering method for free-field conditions over a reflecting plane

ISO/DIS 1680/2 (S12) Acoustics—Test code for the measurement of airborne noise emitted by rotating electrical machinery—Part 2: Survey Method

ISO/DIS 7217 (S12) Acoustics—Agricultural and forestry wheeled tractors and self-propelled machines—Measurement of noise emitted when stationary

ISO/DIS 7216 (S12) Acoustics—Agricultural and forestry wheeled tractors and self-propelled machines—Measurement of noise emitted when in motion

ISO/DIS 7574/4 (S12) Acoustics—Statistical methods for determining and verifying stated noise emission values of machinery and equipment—Part 4: Determining and verifying labeled values for batches of machines

ISO/DIS 7574/3 (S12) Acoustics—Statistical methods for determining and verifying stated noise emission values of machinery and equipment—Part 3: Simple (transition) method for determining and verifying labeled values for batches of machines

ISO/DIS 7574/2 (S12) Acoustics—Statistical methods for determining and verifying stated noise emission values of machinery and equipment—Part 2: Method for determining and verifying labeled values for machines labeled individually

ISO/DIS 7574/1 (S12) Acoustics—Statistical methods for determining and verifying stated noise emission values of machinery and equipment—Part 1: Definitions

ISO/TC 108

ISO/TC 108/SC 2 N 67 First Draft Proposal

ISO/DP 8608 (S2) Mechanical Vibration—Road Surface Profiles—Reporting Measured Data

ISO/DP 8626 (S2) Characteristics of Servo-Hydraulic Test Equipment for Generating Vibration

ISO/DIS 5349.2 (S2 and S3) Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration

The following documents have been received from ISO for comment:

ISO/TC 43 Acoustics

ISO/Draft International Standard (S3) 8201 Audible Emergency Evaluation Signals

The following documents have been received from IEC for vote:

IEC/SC 50A (S2) (Central Office) 165—Amendment to Publication 68-2-6: Test Fc and Guidance: Vibration (Sinusoidal)

Standards from Other Standards Organizations

The following document(s) have been received from CAGI for comment:

S5.1-1984 Measurement of Sound from Pneumatic Equipment. Test code for the (revision and redesignation of ANSI S5.1-1971)

S3 meets in Norfolk

Mr. W. A. Yost, Chairman, has submitted the status report of S3, Bioacoustics. The committee met in May 1984 during the Spring Meeting of the Acoustical Society held in Norfolk, Virginia.

S3-35 Audiometers—*R. Grason, Chair*

A revision of S3.6-1969 was submitted to S3 for ballot. A revised text is expected for ballot.

S3-36 Speech Intelligibility—*J. Webster, Chair*

A draft standard prepared by Sub-group 1, S3.31-198X on methods for determining the threshold level for speech was sent to S3 ballot on 1 November 1983. The working group is considering resolving the negative votes.

At the last meeting, it was recommended that ANSI S3.5-1969 be revised with G. Garinther chairing the group to start this revision. Mr. Kreul reported for Sub-group 2, prior to the meeting, that he has been conducting interviews across the southern part of the U.S. to establish goals for this subgroup.

Mr. Hawley reported for S3-36, Sub-group 3, that he hoped to have a draft standard for ballot by November 1984.

S3-37 Coupler Calibration of Earphones—*M. D. Burkhard, Chair*

Mr. Burkhard reported at the meeting that there was need for work on the revision of ANSI S3.25-1979.

S3-39 (S2) Human Exposure to mechanical Vibration and Shock—*H. E. von Gierke, Chair* (counterpart to ISO/TC 108/SC4)

Resolutions of the SC4 meeting held in Stockholm in September 1983 are available from the Standards Secretariat.

TC 108/SC4 will meet from 17–20 September 1984 in Edinburgh.

S3-43 Method for Calibration of Bone Conduction Vibrator—*D. Dirks, Chair*

Mr. Dirks has reported that the working group is preparing a revision of ANSI S3.13-1972 (R 1977) on Artificial Head-Bone for Calibration of Audiometer Bone Vibrators. The draft should be ready for ballot shortly.

Mr. Lybarger reported that the revision of IEC 373 should be proposed as an ANSI standard.

S3-48 Hearing Aids—*D. A. Preves, Chair*

A draft standard on *in situ* measurement of hearing aids (manikin testing) is in preparation and will soon be submitted for ballot. Other items under study are: correction factors for coupler measurements and standardized plug for electrical inputs to hearing aids.

Mr. Preves reported on specific activities of the working group as follows:

(1) Examining the possibility on paper and with measurements of applying correction factors to 2 cc coupler hearing aid data to predict insertion gain.

(2) Investigating the possibility of standardizing hearing aid to earhook nozzles.

(3) Working with ANSI C18.1 battery committee on further standardizing hearing aid battery dimensions.

S3-54 Biological and Medical Ultrasound—*J. A. Rooney, Chair*

Mr. Rooney reported previously that the AIUM Standard was being prepared for ballot.

S3-56 Criteria for Background Noise for Audiometer Testing—*G. Studebaker, Chair*

It is planned to initiate review of S3.1-1977 with a view toward clarification of the circumstances wherein program goals can be met by testing down to levels higher than 0 dB HTL.

S3-58 Hearing Conservation Criteria—*J. Tonndorf, Chair*

Mr. von Gierke reported that the international standard (ISO 1999) has been approved as an ISO standard. Mr. Tonndorf reported that he was working on preparing a revised draft of ISO 1999 as a national standard.

S3-59 Measurement of Speech Levels—*K. Pearsons, Chair*

The draft standard has been revised and is being submitted for review by members of the working group. The standard will be submitted for letter ballot in June 1984.

S3-60 Measurement of Acoustic Immittance of the Ear—*D. Lilly, Chair*

This working group will consider the activities of the new IEC working group on Acoustic Impedance Measuring Instruments used in Audiology (IEC/SC29C/WG14) in drafting a standard. It is hoped that this document will be balloted shortly.

S3-61 Sound Pressure Distribution Around the Head and Torso—*G. Kuh, Chair*

The paper on Sound Pressure Distribution about the Human Head and Torso was accepted for publication in *JASA* (November 1982). The working group sought suggestions on the precise steps to be taken toward developing a standard. After discussion, at the last meeting, it was agreed that a standard would be desirable and that this information could be used by several working groups.

S3-62 Impulsive Noise with Respect to Hearing Hazard—*D. Johnson, Chair*

A revised document, S3.28-198X, on Standard Methods for the Evaluation of the Potential Effect on Human Hearing of Sound with peak A-weighted Sound Pressure Levels above 120 dB and a peak C-weighted Sound Pressure Level below 140 dB was balloted by S3 on 15 April 1983. The negative comments are being considered by the working group.

Mr. Johnson reported that most of the negative votes had been resolved and that the unresolved comments would be circulated to S3 for review of their former votes.

S3-63 Acoustical Warning Devices—*M. Whitcomb, Chair*

The document, ISO/DP 8201, is being submitted to ISO for issuance as a DIS.

At the meeting, Mr. Whitcomb reported that there had been a lack of coordination in ANSI and that this had resulted in the surfacing of three standards on the same subject, two by the National Fire Protection Association and one by the American Nuclear Society. After discussion of the problem, which had also been discussed at the Acoustical Standards Board in ANSI, it was decided that it would help to specifically include the words "auditory warning signals" in the scope of S3.

Once ANSI's project registry is implemented, the problem of coordination between the different groups and various projects should be alleviated by use of key words.

The Chairman of S3 would look over the scope of S3 in order to check the key words which might be needed, including auditory warning signals. This recommendation will be submitted to S3 ballot in due course.

S3-67 Manikins—*M. D. Burkhard, Chair*

Work is proceeding on a draft document on head and torso simulators within IEC/SC29C/WG13. A national version is expected shortly.

S3-68 Auditory Magnitudes—(vacant)

With the disbanding of S3-74 (see last Minutes), this working group has assumed the title of "Auditory Magnitudes."

The working group will come up with standards in terms of measurement of loudness and annoyance. (S12 will look at applications of some of these functions.)

S3-69 Auditory Trainers—*S. Sinclair, Chair*

An initial draft of a measurement standard for one type of auditory trainer is presently under development.

S3-71 Artificial Mouths—*S. Whitesell, Chair*

At the last meeting, discussion took place on whether to authorize work on the standard on an artificial mouth, for those devices which are intended to produce a sound field for measuring the characteristics of close talking microphones. The working group plans to meet soon.

S3-72 Brainstem Evoked Response—*R. A. Ruth, Chair*

The working group is in the process of further defining the scope of its activities as it applies to the many different forms of measurement of auditory evoked potentials currently in use.

S3-73 Bioacoustical Terminology—*H. Silbiger, Chair*

A computerized data base is being created containing the terms found in S3.20-1973, and others gathered from current S3 standards. These will be checked for continued relevance and accuracy. Any terms defined in standards presumably in draft form may be submitted to the Chair of this working group for possible inclusion.

Additional S3 Business:

Pending approval of the S3 committee, the following new working groups have been suggested:

S3-75 Masking—a group to investigate standardization of masking and detection

S3-76 Computerized Audiometry—a group to prepare a standard on computer-based audiometers

S3-77 High Frequency Audiometry—a group to investigate standards for audiometry above 8000 Hz and to be the U.S. counterpart to similar ISO activities

S3-78 Thresholds—a group to serve as a liaison with the national and international standards activities association with auditory thresholds

S12 meets in Norfolk

Standards Committee S12, Noise, met in Norfolk Virginia on 9 May 1984. The following are the reports of the working groups discussed at the meeting.

S12-1 Advisory Planning Committee—*W. Melnick, Chair*

Mr. Melnick reported on the proposed formation of a new working group in S12 on atmospheric sound propagation, the activity to parallel the international working group on the same subject, ISO/TC 43/SC1/WG24, with Mr. Sutherland as the chair of the national Sub-TAG in S12.

Mr. Melnick also mentioned the new ANSI procedures which called for accredited standards committees to confirm their officers as well as individual experts. (No changes were presently proposed for the S12 officers.)

S12-2 Terminology, Abbreviations and Symbols—*R. K. Hillquist, Chair*

Mr. Hillquist submitted the following report prior to the meeting:

An initial listing of candidate terms is presently being formulated. Also, liaison has been established with ASC Y10, Letter Symbols, with a member of the Working Group acting as ASA representative to that committee.

S12-3 Measurement of Noise from Office and Data Processing Equipment—*L. Luttrell, Chair*

Mr. Luttrell reported at the meeting as follows:

Working group met in Norfolk 9–10 May. A fourth draft revision of S1.29-1979 based on ISO/DIS 7779 and conforming to the ASA style guide is being reviewed and is expected to be ready for letter ballot within three months.

Round robin tests to verify the accuracy statements have been completed at 19 laboratories in the U.S.A. Preliminary results indicate that the reproducibility is better than the 1.5 dB stated. The round robin revealed several problem areas which will be addressed before balloting.

The translation problem with ISO/DIS 7779 has apparently been solved and the TC43/SC1 Secretariat has sent the document to Geneva.

S12-4 IEE/85 Committee on Noise Emitted by Rotating Electrical Machines—*R. G. Bartheld, Chair*

There has been no activity in this working group since the last meeting.

S12-6 Insertion Loss of Outdoor Noise Barriers at Sites of Interest—*W. Bowlby, Chair*

Mr. Bowlby submitted the following report at the meeting:

Draft No. 4 was completed and circulated to S12-6 for review. Additionally, copies were sent to 19 interested members of S12 for comment and to relevant Federal agencies; a total of eight sets of constructive comments were received. Those reviewers are thanked for their help. The Working Group met at the ASA meeting in May 1984 to resolve the comments. Follow-up letters will be sent to each reviewer.

Per our contract with the U.S.D.O.T. Transportation Systems Center, a field evaluation plan was drafted, reviewed, finalized and submitted. Six state transportation agencies and The Federal Highway Administration are assisting on data collection/analysis/reporting in the spring and summer to test the clarity, completeness, and accuracy of the procedures.

A revised draft reflecting the comments and field evaluations will be prepared in the fall.

S12-7 Statistical Sampling Procedures for Noise Emission Requirements—*L. Luttrell, Chair*

Mr. Luttrell submitted the following report at the meeting:

A third draft of S12.3-198X was distributed to negative voters. A meeting with these voters was held in Norfolk to identify further changes to resolve the remaining issues. A new draft will be prepared for 30-day review by S12 before the next meeting.

S12-8 Determination of Interference of Noise with Speech Intelligibility—*M. J. Collins, Chair*

The first task assignment is the review of ANSI S3.14-1977—American National Standard for Rating Noise with Respect to Speech Interference (see item 8, page 8) which is being considered by the working group.

Ms. Collins reported that an initial meeting was held in Norfolk on 8 May 1984 to begin reviewing ANST S3.14-1977.

S12-9 Annoyance Response to Impulsive Noise—*L. Sutherland, Chair*

The document, "Method for Assessment of High Energy Impulse Sounds with Respect to Residential Communities" was submitted to S12 ballot (LB/S12.4/45) on 1 July 1983. The ballot closed on August 1983 with results as reported at the last meeting (see Minutes).

Mr. Sutherland reported prior to the meeting that results of a working group meeting in San Diego in November 1983 and active communication with the negative voters was under way. Resolution of the negative votes is well underway.

S12-10 Hearing Protectors—*C. Nixon, Chair*

The revision of the standard (ANSI S3.19-1974/ASA 1-1975) has been completed and submitted to S12 ballot (LB/S12.6/59) on 16 April 1984. The ballot will close on 28 May 1984.

Mr. Nixon said that S12 should consider making a charge to this working group to prepare a field method of evaluation.

S12-12 Evaluation of Hearing Conservation Programs—*L. Royster, Chair*

Mr. Royster has agreed to chair this working group. Mr. Royster reported that his goal was to come out within 18 months with recommended guidelines.

S12-13 Community Response to Noise Levels—*F. Hall, Chair*

Mr. Hall submitted the following report at the meeting:

The literature review was submitted to *JASA* in November, and has been accepted subject to a few minor revisions. At the same time that it was sent to *JASA*, copies were sent to all those whose work was cited in it, and a few comments have been received from them which should also be incorporated in the final version.

The WG met on 8 May to discuss a draft outline of a standard, and is in general agreement on the outline. Several needs regarding other standards were identified in the meeting, relating to measurement and prediction of noise levels in the community. For existing facilities, measurement issues relate to spatial and temporal sampling, and to measurement locations within the community to best represent the response likely. For proposed facilities, prediction procedures need to be identified which are deemed to be acceptable for standards purposes, particularly for road traffic, airport/aircraft, and industrial noise.

S12-14 Measurement of Noise from Pneumatic Compressors, Tools and Machines—(vacant)

It was proposed that Mr. Kessler be asked to chair this activity.

S12-15 Measurement and Evaluation of Outdoor Community Noise—*P. Schomer, Chair*

A draft standard has been prepared and submitted to S12 for ballot (LB/S12.9/64) on 16 April 1984. It will close on 28 May 1984.

S12-16 Measurement and Evaluation of Motor Vechicle Noise—*L. J. Eriksson, Chair*

The working group met in Detroit in March 1984.

S12-17 Measurement and Evaluation of Aircraft Noise—*R. Linn, Chair*

This group is the counterpart to the SAE A-21 group on aircraft noise.

ISO 3891—procedures for estimating aircraft noise heard on the ground—is due for reaffirmation. Mr. Galloway reported at the last meeting that SAE A-21 was asked to generate comments, and transmit these to Mr. von Gierke for preparation of the U.S. position. It is possible that the international working group activity on aircraft noise (ISO/TC 43/SC1/WG2) will be reactivated.

Mr. Galloway reported that *SAE S6.4, an American National Standard on Perceived Noise Levels* was to be withdrawn by ANSI. The question was raised in S12 whether an S12 working group, independent of the SAE A-21 working group, should be established. It was agreed that the planning committee of S12 should report back at the next meeting on this matter.

On *auditory magnitudes*, Mr. von Gierke expressed the thought that basic work was still needed in this area in S3. This work had been divided, with the formation of S12, and a portion remaining in S12 (Sutherland's working group).

It was agreed that Mr. Galloway and Mr. von Gierke would help the planning committee with their work in reviewing these activities and their apportionment between S3 and S12.

J. Acoust. Soc. Am. 76(3), Sept. 1984; 0001-4966/84/090993-02$00.80;

S12-18 Criteria for Room Noise—*S. L. Yaniv, Chair*

The proposed draft ANSI Standard Procedure for Measuring and Rating Steady-State Room Noise was submitted to ballot (LB/S12.2/26) on 22 September 1982. The ballot closed on 3 November 1982 with results as given previously.

Ms. Yaniv reported at the meeting that she hoped to have draft No. 6 available this summer.

S12-19 Measurement of Occupational Noise Exposure—*J. P. Barry/W. Thornton, Co-Chairs*

The new charge to ISO/TC 43/SC1 (which developed ISO 1999), i.e., to produce a standard on noise at the workplace, which would be comprehensive, was discussed at the last meeting. Factors to be included are noise, annoyance, and other nonauditory health effects at the workplace. It was suggested that this working group could be the national counterpart for the international activity.

Mr. Thornton reported at the meeting as follows:

"The working group has met on a regular basis, typically every 6 to 8 weeks. Excellent progress has been made in developing a draft, which was submitted to the working group for review, discussion, and comments.

"A meeting of the working group was held at the Norfolk ASA meeting on 7 May 1984. Suggestions and changes derived from the meeting are to be incorporated in the draft along with numerous written comments, mostly editorial.

We currently expect to have a draft ready for ballot in the next few months."

It was also agreed that it was more appropriate for this working group to have the title *Measurement of Occupational Noise Exposure*.

S12-20 Specification of the New Machinery at the Operator's Position—*R. D. Bruce, Chair*

Mr. Roth reported for Mr. Bruce that it was hoped to have a good outline for a standard and proposed schedule for its preparation by the next meeting.

S12-21 Determination of Sound Power using Sound Intensity Measurements—*M. J. Crocker, Chair*

Mr. Crocker submitted the following report at the meeting:

Nineteen people were present at the ANSI S12-21 meeting. Of these, six people had also been present at the S1-12 committee meeting earlier on Monday. The scopes of the S12-21 and S1-12 committees were compared and agreement was made to collaborate and minimize overlap. It is understood that S1-12 will concentrate on calibration and arrangement of the probe and on the requirements for the instrumentation. Two of our ANSI S12-21 members (USA and Canada) attended the ISO/TC43/SC1/WG25 meeting on 2 April 1984 in Denmark. A report was made of the progress made by the ISO/TC43/WG1/WG25 committee whose scope is similar to the ANSI S12-21 committee.

The minutes of the last ANSI S12-21 meeting in San Diego were approved. Several other matters were agreed.

It was agreed to send out a survey to potential users of the standards developed by the S12-21 and S1-12 committees. The parts of the ANSI S12-21 intensity standard which were written were reviewed. In addition, volunteers were obtained to write the parts of the ANSI S12-21 standard which remain to be written. These are to be collected, collated and circulated by Alan Wolf of Exxon before the next meeting of ANSI S12-21 to be held at the next Acoustical Society Meeting in Minneapolis in October 1984. The plan is to try to have a standard ready for ballot in about two years' time.

S12-22 Impulse Sound Propagation for Community Noise Assessment—*R. Raspet, Chair*

The working group met and is evaluating the data available.

S12-23 Determination of Sound Power—*P. K. Baade, Chair*

This working group will monitor the sound power series of standards (i.e., S1.30, 31, 32, 33, 34, 35, and 36) and complete the development of S1.37 and S1.38 (the latter to have S12 numbers).

The proposed ANSI Standard S12.5-198X Determination of Sound Power Levels of Noise Sources—Characterization and Calibration of Reference Sound Sources, Draft dated June 1983, was sent to ballot (LB/S12.5/46) on 30 June 1983. (It is the counterpart to ISO/DIS 6926.)

The ballot closed on 16 August 1983 with results as given in the last Minutes. Mr. Baade is working to resolve the negative votes, and reported at the meeting as follows:

Working Group S12-23 discussed the CAGI Sound Test Code announced to S12 (see S12-14 and national documents processed) at its meeting in Norfolk on 1984-05-07 with the changes that will have to be made in section 5 to make the two-surface method acceptable.

We are planning to incorporate the improved two-surface method in the upcoming revision of ANSI Standard S1.34-1979.

S12-24 Placement of Personal Noise Monitoring Microphones—*A. Burke, Chair*

This is a new working group chaired by Mr. Burke.

Documents without working groups submitted to S12 Ballot

The document entitled *Standard Methods for the Measurement of Impulse Noise, S12.7-198X*, was formerly under the jurisdiction of S1 and designated as S1.28. It has been revised and submitted to S12 ballot (and to S1 for information) as LB/S12.7/61 on 15 March 1984.

The ballot closed on 26 April 1984 with results as given in the Minutes.

Mr. Johnson reported at the meeting that it was considered that all substantial issues could be resolved with the negative voters, and that a meeting had been held with Mr. Young (Eldred, Embleton, Johnson, and von Gierke present) to address the issues. As a key to resolution of the negative comments, Dr. Young had agreed to provide a complete set of figures showing various ways of presenting the spectra of a typical sonic boom by 10 June 1984.

International Matters

Mr. von Gierke mentioned the fact that S12 had requested TAG responsibility for a new Subcommittee in ISO, *TC 94/SC12 on Hearing Protection* (under the new ISO Technical Committee TC 94 on Safety).

Recommendations to confirm the following ISO/TC 43 standards, published or confirmed in 1979, were submitted to ANSI on 20 March 1984 on recommendation of the Technical Advisor, following input of respective S Committee Chairs:

ISO 131 Acoustics	Expression of physical and subjective magnitudes of sound or noise in air
ISO 2204 Acoustics	Guide to international standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings
ISO 2249 Acoustics	Description and measurement of physical properties of sonic booms
ISO 3746 Acoustics	Determination of sound power levels of noise sources—survey method

Please see the attached report on international documents processed by the Standards Secretariats.

Report on National Documents submitted to S12 Review

The following documents were received from ANSI for *comment* via ANSI's public comment period.

- SAE J 1372 June 83, Sound Power Determination—Earthmoving Machinery Static Condition

announced to S12 (S12/55) on 21 October 1983. No S12 response was submitted because the document was considered technically correct (coordinator's response dated 1 December 1983).

- BSR/SAE Air 1672B, Practical Methods to Obtain Free-Field Sound Pressure Levels From Acoustical Measurements Over Ground Surfaces (new standard)

announced to S12 (S12/56) on 4 November 1983. No comments were received on this document as a result of the circulation and S12 therefore abstained from comment (letter from coordinator dated 19 December 1983).

- **Draft Standard ISA dS75.07 dated November 1983**
  Laboratory Measurement of Aerodynamic Noise generated by Control Valves

announced to S12 (S12/57) on 27 December 1983. S12 comments were submitted to the Instrument Society of America on 13 March 1984.

- ASHRAE Standard 68-78R, "Method of Testing In-Duct Sound Power Measurement Procedure for Fans"

announced to S12 (S12/62) on 30 March 1984. Mr. Baade is coordinating the S12 Comments.

- CAGI S5.1-198X Test Code for the Measurement of Sound from Pneumatic Equipment

announced to S12/(S12/63) on 1 April 1984. Mr. Kessler is coordinating the S12 comments.

Report on ISO/TC43 Acoustics and ISO/TC43/SC1 Noise-documents processed by the Standards Secretariat from November 1983 through April 1984

The following documents were received for *vote* by the U.S. Member Body:

- ISO/DIS 3747 Determination of sound power levels of noise sources—
  Survey method using a reference sound source

- ISO/DIS 3748 Determination of sound power levels of noise sources—
  Engineering method for small, nearly omnidirectional sources under free-field conditions over a reflecting plane

announced to S12 (S12/50) on 15 August 1983 with comments coordinated by P. K. Baade. The U.S. position on ISO/DIS 3747 (to accept with editorial corrections) was submitted to ANSI on 31 January 1984. The U.S. position on ISO/DIS 3748, affirmative with editorial comments, was submitted to ANSI on 4 April 1984.

- ISO/DIS 1996/2 Description and measurement of environmental noise;
  Acquisition of date pertinent to land use
- ISO/DIS 1996/3 Description and measurement of environmental noise;
  Application to Noise limits

announced to S12 (S12/51) on 15 August 1983 with comments coordinated by P. Schomer. The U.S. position on ISO/DIS 1996/2 (negative with comments) was submitted to ANSI on 4 January 1984. The U.S. position on ISO/DIS 1996/3 (to abstain with comments) was submitted to ANSI on 5 March 1984.

- ISO/DIS 6081.2 Acoustics—Noise emitted by machinery and equipment—
  Guidelines for the preparation of test codes of engineering grade requiring noise measurements at the operator's position

announced to S12 (S12/58) on January 1984 with comments coordinated by R. D. Bruce. The U.S. submitted an affirmative vote with comments on 13 March 1984. The U.S. position was transmitted to Geneva on 21 March 1984.

ABSTRACTS FROM THE CURRENT LITERATURE

ABSTRACT CONTENTS

AVAILABILITY OF PUBLICATIONS ABSTRACTED

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

Periodical articles, society papers, and papers presented at conferences may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

Government reports may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

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A List of Periodicals Scanned is published in issues, 1, 6, and 12.

MECHANICAL SYSTEMS

ROTATING MACHINES

85-1
Nonlinear Torsional Vibrations of a Rotating Shaft System with a Magnet Coupling
H. Kojima, K. Nagaya
Gunma Univ., 1-5-1 Tenjin-cho, Kiryu, Gunma 376, Japan
Bull. JSME, 27 (228), pp 1258-1263 (June 1984) 9 figs, 2 refs

KEY WORDS: Shafts, Torsional vibration, Couplings

In this paper, the nonlinear torsional vibrations of a rotating shaft system having a disk and a magnet coupling consisting of rare-earth magnets are investigated analytically. The driver of the magnet coupling is excited by sinusoidal motion, and the disk is subjected to constant load torque. Besides the harmonic vibration, the one-second order and the one-third order subharmonic vibrations are obtained. Numerical calculations are carried out by the Newton-Raphson method, and the influence of the load torque on the nonlinear torsional vibrations are investigated.

85-2
Combination Tones in a Rotating Shaft System
T. Yamamoto, Y. Ishida, T. Ikeda, A. Hida
Nagoya Univ., Chikusa-ku, Nagoya, Japan
Bull. JSME, 27 (228), pp 1194-1202 (June 1984) 15 figs, 1 table, 13 refs

KEY WORDS: Shafts, Resonant response

The restoring force of an elastic shaft supported by ball bearings has nonlinear spring characteristics. In such a rotating shaft system, various kinds of forces due to the unbalance of a rotor, irregularity of balls, and so on, work and consequently combination tones occur. The characteristics of all kinds of combination tones obtained experimentally and theoretically are discussed.

85-3
Structural Dynamics of Rotating Bladed-Disk Assemblies Coupled with Flexible Shaft Motions
R.G. Loewy, N. Khader
Rensselaer Polytechnic Inst., Troy, NY
AIAA J., 22 (9), pp 1319-1327 (Sept 1984) 14 figs, 41 refs

KEY WORDS: Flexible shafts, Blades, Disks, Eigenvalue problems, Mode shapes

A classical structural dynamics approach is used to couple the motion of a flexible bladed disk typical of modern aircraft turbines to a rotating, flexible shaft. Transformations between fixed and rotating coordinate systems, Lagrange's equations, and routine manipulation lead to a system of second-order differential equations with constant coefficients. Flexible disk displacements transverse to the plane of rotation and radial and tangential as well are accounted for. Rigid disk translations along, and rotations about, axes normal to the undeformed shaft axes are also included. Using this method, the Pratt & Whitney first-stage compressor/fan of the "E^3" engine has been analyzed for a wide range of shaft flexibilities and shaft speeds. Some of the one-diametral node frequencies are shown to be affected significantly by shaft degrees of freedom with stiffness values in the general range of design practice. Coriolis forces are also shown to affect natural frequencies appreciably where there is strong coupling between certain modes.

85-4
The Dynamic Properties of Flexible Rotors, Supported in Anisotropic Bearings
O. Danek
Inst. Thermomechanics, Czechoslovak Academy of Sciences, Prague, Czechoslovakia
Strojnícky Časopis, 35 (3), pp 229-240 (1984) 7 figs, 10 refs (In Czech)

KEY WORDS: Flexible rotors, Natural frequencies, Forced vibration, Balancing techniques

The rotor is considered as a non-conservative dynamic, evolutionary system whose physical parameters depend on functional parameters. From this standpoint, eigen and forced vibrations are studied and the concepts of stability, resonance, and balancing are explained.

85-5
Economic Solutions of Rotor Dynamics Problems
M. Balda
SKODA, k.p. PLZEN, Central Res. Inst., Plzen, Czechoslovakia
Strojnicky Časopis, 35 (3), pp 241-260 (1984) 3 figs, 2 tables, 22 refs (In Czech)

KEY WORDS: Flexible rotors, Eigenvalue problems, Random excitation, Statistical linearization, Discrete Fourier transform

The paper deals with approximate solutions of dynamics problems of rotors by means of methods which are applicable even on small computers. First, the approximate solution of a complex eigenvalue problem is presented, concerning rotors supported in many flexible damped bearings possessing spatial couplings. Planar modes of flexibly supported rotors are exploited for the purpose. For the same rotors, methods for calculating responses caused by arbitrary excitation are presented. They are based on the application of matrix exponential, and/or on discrete Fourier transform. A proposal is made for calculating nonlinear vibrations via statistical linearization or quasilinearization.

85-6
Stability of Unsymmetrical Rigid Rotor Supported by Self-Acting Gas-Lubricated Journal Bearings
S. Yoshimoto, Y. Nakano
Science Univ. of Tokyo, Kagurazaka, Shinjuku-ku, Tokyo, Japan
J. Lubric. Tech., Trans. ASME, 105 (4), pp 656-661 (Oct 1983) 8 figs, 12 refs

KEY WORDS: Rigid rotors, Gas bearings, Stability

To determine the threshold of instability for an unsymmetrical rigid rotor supported by two identical self-acting, plain-cylindrical gas journal bearings, a theoretical approach is made using quasi-static nonlinear PH method. Influence of various parameters affecting the threshold of instability of the unsymmetrical rotor is experimentally shown and compared with the theoretical results. The experimental variables considered in this paper include bearing load, bearing length, bearing clearance, the axial deviation of the center of gravity from the center of rotor span. Good agreement was obtained between the experimental and theoretical results.

85-7
Simulation of Centrifugal Compressor Transient Performance for Process Plant Applications
I. Macdougal, R.L. Elder
Cranfield Inst. of Tech., Cranfield, UK
J. Engrg. Power, Trans. ASME, 105 (4), pp 885-890 (Oct 1983) 6 figs, 15 refs

KEY WORDS: Centrifugal compressors, Transient response, Mathematical models, Surges, Fluid-induced excitation

The development of a theoretical model capable of simulating centrifugal compressor transient performance (including compressor surge) is detailed. Simulation results from a Fortran computer program are compared with measured compressor transient data. Good simulation of compressor transients between stable operating points, and compressor presurge flow oscillations has been obtained. General application criteria are presented for the geometric distribution of model elements within a compressor system. Model applications and future work are outlined.

85-8
Aerodynamic Tests on Centrifugal Process Compressors -- the Influence of the Vaneless Diffusor Shape
K. Ludtke

Borsig GmbH, Berlin, W. Germany
J. Engrg. Power, Trans. ASME, 105 (4), pp 902-909 (Oct 1983) 8 figs

KEY WORDS: Centrifugal compressors, Aerodynamic loads, Experimental data, Geometric effects

Shop performance tests, conducted on a four-stage industrial centrifugal compressor, are reported.

85-9
On the Transient Interaction of Centrifugal Compressors and Their Piping Systems
C.R. Sparks
Southwest Res. Inst., San Antonio, TX 78284
J. Engrg. Power, Trans. ASME, 105 (4), pp 891-901 (Oct 1983) 23 figs, 2 tables

KEY WORDS: Centrifugal compressors, Piping systems, Surge, Fluid-induced excitation

The problems of surge and other low-frequency pulsation phenomena in centrifugal compressors are described in terms of both machine characteristics and the flow impedance characteristics of its attached piping. Flow stability criteria are presented in terms of net modal damping, as the combination of piping acoustic damping and equivalent negative damping of the compressor in the surge region of its performance curve. Surge and instability frequencies are related to acoustic reactance of the piping system. Finally, theoretical concepts are verified both by electrical analog models and by field and laboratory data on real compressors. This paper provides some new and significant findings on the dynamic interaction of centrifugal compressors with piping systems and describes the basic phenomena underlying these interactions. Good agreement is shown between predicted and measured surge frequencies, and for those termed "piping resonance surge" produced by high flow offsets or flat spots in the head curve.

85-10
Component Synthesis of Multicase, Rotating Machinery Trains by the Generalized Receptance Approach
A.B. Palazzolo, Bo Ping Wang, W.D. Pilkey
Southwest Res. Inst., San Antonio, TX 78284
J. Engrg. Power, Trans. ASME, 105 (4), pp 941-946 (Oct 1983) 2 figs, 3 tables, 11 refs

KEY WORDS: Rotating machinery, Component mode synthesis, Mobility method

A method is presented for computing the eigenvalues of multicase, coupled, rotating machinery trains. The method is based on a synthesis technique which utilizes generalized receptance formulas, previously derived by the authors. These formulas improve the accuracy of the computed receptance when only an incomplete set of modes is available. A nonsynchronous, gyroscopic, two-rotor example is examined to illustrate the synthesis procedure.

85-11
Fan Noise Reduction Achieve by Removing Tip Flow Irregularities Behind the Rotor -- Forward Arc Test Configurations
J.H. Dittmar, R.P. Woodward, M.J. Mackinnon
NASA Lewis Res. Ctr., Cleveland, OH
Rept. No. E-2047, NASA-TM-83616, 17 pp (1984) N84-23235

KEY WORDS: Fan noise, Noise reduction

The noise source caused by the interaction of the rotor tip flow irregularities (vortices and velocity defects) with the downstream stator vanes were studied. Fan flow was removed behind a 0.508 meter diameter model turbofan through an outer wall slot between the rotor and stator. Noise measurements were made with far-field microphones positioned in an arc about the fan inlet and with a pressure transducer in the duct behind the stator. Little tone noise reduction was observed in the forward arc during flow removal; possibly because the rotor-stator interaction noise did not propagate upstream through the rotor. Noise reductions were made in the duct behind the stator and the largest decrease occurred with the first increment of flow removal. This

result indicates that the rotor tip flow irregularity-stator interaction is as important a noise producing mechanism as the normally considered rotor wake-stator interaction.

METAL WORKING AND FORMING

85-12
Rational Measuring Techniques for Determination of the Static and Dynamic Behaviour of Machine Tools (Rationelle Messverfahren zur Bestimmung des statischen und dynamischen Verhaltens von Werkzeugmaschinen)
W.G. Hempel, H. Otto, R. Schosser, Werkzeugmaschinenkombinat "Fritz Heckert" Karl-Marx-Stadt, German Dem. Rep.
Maschinenbautech., 33 (4), pp 152-154 (1984) 5 figs (In German)

KEY WORDS: Machine tools, Stability, Computer-aided techniques

Microcomputer and on-line techniques for the determination of static and dynamic properties of machine tools are described.

85-13
The Force in a Die Forging Hammer
H.W. Haller
J. Engrg. Indus., Trans. ASME, 105 (4), pp 270-275 (Nov 1983) 5 figs, 7 refs

KEY WORDS: Forging machinery, Force coefficients

The blow of a die forging hammer in its nature and quantity is influenced by the behavior of the forging and its deformation status. In forging, the hammer supplies the energy necessary for plastic deformation as well as the force necessary to coin the forging. The main purpose of this paper is to determine, in hammer forging, how the forces are generated and how the hammer energy is transformed into energies useful for deformation and lost in vibration noise. Theoretical prediction of the forces is possible by considering the energy balance between kinetic energy of the ram and energies used for deformation and lost in rebounding of the ram and the acceleration of the anvil. The results given in this paper show that it is possible to predict at least the upper limits of the generated forces for a given size of an anvil hammer.

MATERIALS HANDLING EQUIPMENT

85-14
Dynamic Analysis of Rack Stacker by FEM
P. Solek, J. Stradiot
Slovak Technical Univ., Bratislava, Czechoslovakia
Strojnícky Časopis, 35 (3), pp 273-286 (1984) 11 figs, 1 table, 11 refs (In Slovak)

KEY WORDS: Materials handling equipment

The article is about the calculation of eigenfrequencies, eigenvectors and dynamic stresses of rack stacker. Solution is given by the method of finite elements.

85-15
Investigation of Loading from Horizontal Side Forces of an Overhead Crane as a Random Phenomenon
J. Gajdoš
Mech. and Elect. Engrg. Faculty of the High Transport and Communication School, Žilina, Czechoslovakia
Strojnícky Časopis, 35 (3), pp 325-337 (1984) 7 figs, 3 refs (In Slovak)

KEY WORDS: Cranes, Overhead cranes, Random excitation

The paper describes methods of investigation of horizontal side forces appearing during overhead crane crossing at a crane track as a random phenomenon. They are based on a general model of a random behavior of a given load, for which basic parameters are shown. The presented methods show inaccuracies of classification of this load as a random phenomenon compared

with the Czechoslovak Standard CSN 27 0103.

85-16
Study on Dynamic Stability of a Truck Crane Carrier. 1st Report, Backward Stability of a Carrier with Outriggers
Y. Kato, H. Ito
Kobe Steel Ltd., Akashi, Japan
Bull. JSME, 27 (228), pp 1251-1257 (June 1984) 9 figs, 1 table, 4 refs

KEY WORDS: Cranes, Trucks, Dynamic stability

This paper deals with the backward stability of a truck crane the carrier of which is supported by outriggers during crane working. Thus the minimum acceptable backward stability of a truck crane can be easily determined for any carrier dimension and specification.

STRUCTURAL SYSTEMS

BUILDINGS

85-17
Strong Motion Drift Estimates for R/C Structures
J.P. Moehle
Univ. of California, Berkeley, CA
ASCE J. Struc. Engrg., 110 (9), pp 1988-2001 (Sept 1984) 6 figs, 15 refs

KEY WORDS: Buildings, Reinforced concrete, Ground motion, Seismic response spectra

A simple procedure is described by which to obtain estimates of maximum inelastic response displacements for a certain class of reinforced concrete building structures subjected to strong ground motions. The procedure is based on elastic response spectrum analysis techniques. Change in vibration period and energy dissipation attributable to inelastic response are taken into account. The procedure is tested by comparing maximum computed displacements with those measured in numerous tests of small-scale structures. Results of the comparison indicate that the procedure produces good results for a variety of structural systems and over a wide range of response.

85-18
Seismic Response of Vertically Irregular Structures
J.P. Moehle
Univ. of California, Berkeley, CA
ASCE J. Struc. Engrg., 110 (9), pp 2002-2014 (Sept 1984) 9 figs, 3 tables, 7 refs

KEY WORDS: Frames, Multistory buildings, Reinforced concrete, Seismic response

Seismic response of four irregular reinforced concrete test structures is interpreted using static analysis methods. The four test structures were simplified models of multi-story building frames comprising frames and frame-wall combinations. Discontinuities in the vertical plane of the structures were introduced by discontinuing the structural walls at various levels. It is found that standard limit analysis and static inelastic analysis provide good measures of strength and deformation characteristics under strong earthquake motions.

85-19
Non-Linear Torsional Coupling in Symmetric Structures
O.A. Pekau, P.K. Syamal
Concordia Univ., Montreal, Quebec, Canada H3G 1M8
J. Sound Vib., 94 (1), pp 1-18 (May 8, 1984) 11 figs, 11 refs

KEY WORDS: Buildings, Torsional response

A study of the initiation of torsional response in symmetric building structures subjected to harmonic lateral ground excitation is presented. Earlier studies are extended by an examination of the importance of torsional damping as well as the distribution

and geometric arrangement of the lateral load-resisting elements. In addition, the relationship between two different sets of stability diagrams derived in previous studies is clarified. Finally, the susceptibility to nonlinear coupling is summarized in the form of generalized criteria, for both critical damping and the size of the regions of torsional instability. These are applicable to general configurations of load-resisting elements encountered in symmetric structural systems.

FOUNDATIONS

85-20
Soil-Structure Interaction. A General Method to Calculate Soil Impedance
M. Farvacque, F. Gantenbein
CEA Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France
Rept. No. CEA-CONF-6990, CONF-8308-05-73, 12 pp (Aug 1983) (Intl. Conf. on Struc. Mechanics in Reactor Tech., Chicago, IL, Aug 22, 1983)
DE84750721

KEY WORDS: Foundations, Nuclear power plants, Buildings, Soil-structure interaction, Seismic response

This paper presents a general method to calculate soil impedances which is based on the computation of the impulsive response of the soil using an axisymmetric 2D finite element code (INCA). The Fourier transform of this response is made in the time interval before the return of the reflected waves on the boundaries of the F.E. domain. This procedure which limits the perturbing effects of the reflections is improved by introducing absorbing boundary elements. A parametric study for homogeneous and layered soils has been carried out using this method.

85-21
Hybrid Modelling of Soil-Structure Interaction in Layered Media
T.J. Tzong, J. Penzien
Univ. of California, Berkeley, CA
Rept. No. UCB/EERC-83/22, NSF/CEE-83035, 156 pp (Oct 1983) PB84-192178

KEY WORDS: Soil-structure interaction, Layered materials, Finite elment technique, Impedance technique, Hybrid simulation

The hybrid modeling approach, which effectively solves soil-structure interaction problems, is extended for uses in layered soil media. This approach partitions the entire structure-soil system into a near field. This consists of the structure and a portion of its surrounding soil, modeled by the finite element method, and a far-field which is responsible for energy traveling away from the near field represented by an impedance model. Two analytical methods, appropriate to different layered soil systems, are employed to simulate the semi-infinite far-field region. The system identification method is applied to the single-layer half-space in which a rigorous representation of the far-field is difficult to obtain by direct solution. A boundary solution method is developed to calculate the exact far-field impedance matrix for cases involving layers of soil having a rigid lower boundary.

PRESSURE VESSELS

85-22
Experimental Techniques for Fatigue Studies
R.M. Wetzel
Rosemount, Inc., Eden Prairie, MN
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 447-480, 4 figs, 3 refs

KEY WORDS: Piping systems, Pressure vessels, Fatigue life, Testing techniques

The article documents the changes and improvements in experimental technologies used to investigate and explore fatigue crack initiation and behavior of metals and components used in pres-

sure vessels and piping systems. It also briefly discusses experimental developments likely to occur in the eighties. It concludes that powerful experimental tools exist and will continue to be developed to investigate and understand the complex relationships between stress, strain, time, temperature and fatigue failure. A brief bibliography provides an introduction to experimental developments.

POWER PLANTS

85-23
Substructure Method to Compute the 3D Fluid-Structure Interaction During Blowdown
D. Guilbaud, F. Axisa, F. Gantenbein, R.J. Gibert
CEA Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France
Rept. No. CEA-CONF-6987, CONF-8308-05-74, 11 pp (Aug 1983) (Intl. Conf. on Struc. Mechanics in Reactor Tech., Chicago, IL, Aug 22, 1983)
DE84750722

KEY WORDS: Fluid-structure interaction, Substructuring methods, Nuclear reactor components

This paper describes a method based on a substructure procedure: the vessel, internals and contained fluid are axisymmetrically described (AQUAMODE computer code). The pipes and contained fluid are monodimensionally described (TEDEL-FLUIDE Computer Code). These substructures are characterized by their natural modes. Then, they are connected to another (connection of both structural and fluid nodes) the TRISTANA computer code. This method allows to compute correctly and cheaply the 3D fluid-structure effects. The treatment of certain nonlinearities is difficult because of the modal characterization of the substructures.

85-24
3 D Seismic Analysis of Pool Type LMFBR Vessel and Internals
F. Brabant, F. Gantenbein, and R.J. Gibert
CEA Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France
Rept. No. CEA-CONF-6993, CONF-8308-05-70, 10 pp (Aug 1983) (Intl. Conf. on Struc. Mechanics in Reactor Tech., Chicago, IL, Aug 22, 1983)
DE84750718

KEY WORDS: Nuclear reactors, Shells, Seismic analysis

This paper presents the specific method used to calculate the coupling effects of the natural modes of the different substructures due to the 3 D fluid volumes. The first results of the seismic analysis of the internals: actually the calculation of the assembled structure is not yet achieved. However some intermediate results are given: natural modes of the substructures, coupling coefficients due to the fluid.

85-25
Review of LOCA Related Mechanical Problems and Analysis Methods
R. Krieg
Kernforschungszentrum Karlsruhe GmbH, Inst. fur Reaktorentwicklung, Fed. Rep. Germany
"Pressure Vessels and Piping: Design Technology -- 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 323-332, 4 figs, 64 refs

KEY WORDS: Nuclear reactors, Fluid-structure interaction, Pressure vessels

In most research programs in light water reactor safety, theoretical and experimental investigations of loss-of-coolant accidents play an important role. In this paper, the structural dynamics aspects are discussed, especially the dynamic fluid-structure interaction.

85-26
Dynamic Structural Analysis of a Head Assembly for a Large Loop-Type LMFBR
R.F. Kulak, C. Fiala

Argonne National Lab., Argonne, IL
ASME Paper No. 84-PVP-41

KEY WORDS: Nuclear reactors, Impact response

An investigation is presented on the dynamic structural response of the primary vessel's head closure to slug impact loadings generated from a 1000 MJ source term. Two designs were considered for the deck structure: a reference design and an alternate design.

85-27
Poisson's Ratio Correction in Elastic Analysis of Low Cycle Fatigue
D. Moulin, R.L. Roche, B. Autrusson
CEA Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France
Rept. No. CEA-CONF-6992, CONF-8308-05-71, 12 pp (Aug 1983) (Intl. Conf. on Struc. Mechanics in Reactor Tech., Chicago, IL, Aug 22, 1983)
DE84750719

KEY WORDS: Nuclear power plants, Fatigue life

During the operation of nuclear plants, components experience low-cycle fatigue due to thermal transients. A good knowledge of the local strain range is therefore highly desirable for low-cycle fatigue analysis. There are two basic discrepancies between the plastic behavior of the material and the linear elastic model. The first is the nonlinear stress/strain relationship, which mainly affects the strain range in the vicinity of stress raisers. The second is that plastic deformation shows no change in volume. This paper covers the corrective action related to this absence of volume variation.

OFF-SHORE STRUCTURES

85-28
Fracture Control and Reliability for Welded Tubular Structures in the Ocean
P.W. Marshall
Shell Oil Co., Houston, TX
U.S. National Congress of Appl. Mechanics, Proc. of the 9th, Cornell Univ., Ithaca, NY, June 21-25, 1982, ASME, 1982, pp 339-350, 14 figs, 24 refs

KEY WORDS: Off-shore structures, Fracture properties

This paper presents some simple, but useful, concepts for quantifying structural redundancy, and illustrates their application to fixed offshore platforms.

VEHICLE SYSTEMS

GROUND VEHICLES

85-29
A Study on the Mechanisms of the Generation of the Wheel/Rail Noise and Its Transmission to the Vehicle (An Examination Based on the Results of Narrow Band Frequency Analysis)
H. Arai, B. Mouri, Y. Zenda
Railway Technical Res. Inst., JNR, Kokubunji, Japan
Bull. JSME, 27 (228), pp 1210-1217 (June 1984) 16 figs, 3 refs

KEY WORDS: Rail-wheel interaction, Noise generation, Noise transmission

The mechanisms of the generation of the wheel/rail noise and its transmission to the vehicle in high speed operation on an almost straight track like that of SHINKANSEN were studied. Tests were carried out on the SHINKANSEN test track and the results were examined by narrow band frequency analysis. It was concluded that the contribution of the noise due to the vibration of a wheel and a bogie frame to the train noise is small. Their damping is not effective and the internal noise is mostly due to the contribution of the air-borne noise transmitted through the floor.

85-30
NASTRAN Analysis of Nuclear Effects on Helicopter Transparencies
P.T. Lin, J.S. Jorgenson
Goodyear Aerospace Corp., Litchfield Park, AZ
(Conf. on Aerospace Transparent Materials and Enclosures, Scottsdale, AZ, July 11-14, 1983, pp 1083-1095) AD-P003 234

KEY WORDS: Nuclear weapons effects, Helicopters, Windows, NASTRAN (computer programs)

This paper deals with the linear and geometric nonlinear analysis of the gunner's window on the AH-1S Cobra helicopter in response to a nuclear overpressure environment. Both monolithic stretched acrylic and multilayered tranparency configurations are considered in this report. Comparison analyses using both the NASTRAN finite element program and classical Timoshenko plate theory show good agreement. Results indicate that geometric nonlinear mathematical models are more realistic representations of transparency response to nuclear overpressure loading in the range considered. It is shown that the classical analysis of a simplified equivalent configuration serves as a useful checkpoint. Finite element programs, such as MSC/-NASTRAN, are the necessary analytical tools to examine the complicated configurations and loading conditions.

85-31
Validation of the MAGNA (Materially and Geometrically Nonlinear Analysis) Computer Program for Nonlinear Finite Element Analysis of Aircraft Transparency Bird Impact
R.E. McCarty, J.L. Hart
Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH
52 pp (Dec 1983) (Conf. on Aerospace Transparent Materials and Enclosures, Scottsdale, AZ, July 11-14, 1983, pp 921-972) AD-P003 229

KEY WORDS: Aircraft windows, Bird impact, Computer programs, Finite element techniques

The approach taken for validation of MAGNA is based on the simulation of full scale bird impact tests followed by a comparison of the experimental data with that computed by MAGNA. To date, five of these validation studies have been accomplished and several more remain to be conducted. This paper summarizes the results of the validation studies which have been completed to date and lists the user guidelines which have been established in the process. These first validation studies may be characterized as analyses of simple structures. Only single transparent panels have been analyzed as opposed to complex systems of multiple panels joined by metallic edgemember support structure.

85-32
Windshield Problems on UK Operated Transport Sized Jet Aircraft 1976-1982
J. Thorpe
Airworthiness Div., Civil Aviation Authority, Redhill, UK
10 pp (1983) (Conf. on Aerospace Transparent Materials and Enclosures, Scottsdale, AZ, July 11-14, 1983, pp 910-919) AD-P003 228

KEY WORDS: Aircraft windows, Impact response, Reviews, Bird impact

The paper reviews windshield problems reported between 1976 and 1982 on UK operated sized jet aircraft. The paper shows that external causes such as hail (four cases) and birds or lightning (one case each) are outweighed by problems with the windshield itself (157 cases).

85-33
Theoretical Evaluation of the Structural Performance of Swedish Fighter Aircraft Windshields Subjected to Bird Impact
L.A. Samuelson, F. Nilsson, L. Somas
IFM Akustikbyran A.B., Stockholm, Sweden
35 pp (Dec 1983) (Conf. on Aerospace Transparent Materials and Enclosures, Scottsdale, AZ, July 11-14, 1983, pp 1083-1095) AD-P003 235

KEY WORDS: Aircraft windows, Bird impact

High velocity bird impact characteristics were studied theoretically and the critical velocity, windshield deflection, and associated phenomena in Swedish fighter aircraft were predicted. Results were used to optimize the test program and to propose design improvements for existing crew enclosures.

85-34
Current Problems and Progress in Transparency Impact Analysis
R.A. Brockman
Res. Inst., Dayton Univ., OH
26 pp (Dec 1983) (Conf. on Aerospace Transparent Materials and Enclosures, Scottsdale, AZ, July 11-14, 1983, pp 1057-1082) AD-P003 233

KEY WORDS: Windows, Impact response

The design of aircraft transparencies for impact resistance poses a number of difficult problems for the structural analyst. Prominent among these are the accurate modeling of the transparency and its dynamic response, characterization of the construction materials, and evaluation of the applied loadings resulting from soft-body impact. This paper reviews current practices for mathematical modeling of transparency impacts, discusses problem areas in current analysis capabilities, and summarizes some current research on methods for impact simulation.

85-35
Parametric Studies of the T-38 Student Windshield Using the Finite Element of Code MAGNA (Materially and Geometrically Nonlinear Analysis)
R. Nash
Res. Inst., Dayton Univ., OH
16 pp (Dec 1983) (Conf. on Aerospace Transparent Materials and Enclosures, Scottsdale, AZ, July 11-14, 1983, pp 1040-1055) AD-P003 232

KEY WORDS: Aircraft windows, Bird impact, Finite element technique, Computer programs

The parametric studies examine the effect of structural variations on the nonlinear dynamic response of the T-38 student windshield/support structure system to bird impact. The studies were conducted using the MAGNA (Materially and Geometrically Nonlinear Analysis) finite element computer program. Both static and dynamic analyses were performed, examining the effects of changes to the transparency stiffness and intensity of the applied load, both coupled and uncoupled. Significant results of the finite element analysis include transparency deflection peak load versus transparency stiffness, and resultant force plots along the aft arch. A discussion of the application of the finite element method to the birdstrike problem is also presented.

85-36
MAGNA (Materially and Geometrically Nonlinear Analysis) Computer Simulation of Bird Impact on the F-15 Aircraft Canopy
R.E. McCarty
Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH
36 pp (Dec 1983) (Conf. on Aerospace Transparent Materials and Enclosures, Scottsdale, AZ, July 11-14, 1983, pp 973-1008) AD-P003 230

KEY WORDS: Computer programs, Finite element techniques, Aircraft windows, Bird impact

The F-15E aircraft is one of two evolutionary aircraft types which are currently being evaluated by the USAF for future low level, high speed, and attack and interdiction missions. It is a two-place aircraft and is proposed to utilize the windshield/canopy transparency system which has been in production for some years for the TF-15 aircraft. The canopy portion of this transparency system has a high lofted shape and offers considerably more presented frontal area than the canopy for one-place models of the aircraft. As a result of the lofted shape of the TF-15 canopy and the mission of the aircraft, the hazard of transparency bird impact during flight operations is significant. Some proposals to increase the level of bird impact protection for the F-15E canopy

have already been aired. The availability of an analysis method which could accurately predict the dynamic structural response of such proposed canopy designs to bird impact loading would be valuable in establishing the merits of each. If the MAGNA nonlinear finite element analysis program could be validated for F-15 transparency analysis it would have significant potential for saving time and cost in the development of improved F-15E transparencies.

MISSILES AND SPACECRAFT

85-37
On Transient Dynamics and Stability of Large Space Structures
V.J. Modi
Univ. of British Columbia, Vancouver, B.C., Canada
U.S. National Congress of Appl. Mechanics, Proc. of the 9th, Cornell Univ., Ithaca, NY, June 21-25, 1982, ASME, 1982, pp 249-258, 13 figs, 22 refs

KEY WORDS: Spacecraft components, Stability

The paper presents results of a study aimed at assessing dynamical response and stability of orbiting spacecraft during deployment and/or retrieval of mass elements leading to time dependent inertias. In particular two classes of problems are discussed: flexible beam type appendages such as solar panels, antennae, and preassembled trusses deploying from a space platform in an orbit and space shuttle based tethered systems. The study suggests that with critical combinations of parameters the systems can become unstable, however, suitable control strategies are available which can restore stability.

85-38
Controller Design for Flexible, Distributed Parameter Mechanical Arms via Combined State Space and Frequency Domain Techniques
W.J. Book, M. Majette
Georgia Inst. of Tech., Atlanta, GA 30332
J. Dynam. Syst., Meas. Control, Trans. ASME, 105 (4), pp 245-254 (Dec 1983) 4 figs, 11 refs

KEY WORDS: Spacecraft, Control equipment, Frequency domain method

The potential benefits of the ability to control more flexible mechanical arms are discussed. A justification is made in terms of speed of movement. A new controller design procedure is then developed to provide this capability. It uses both a frequency domain representation and a state variable representation of the arm model. The frequency domain model is used to update the modal state variable model to insure decoupled states. The technique is applied to a simple example with encouraging results.

85-39
Dynamic Analysis of Electrodynamic Satellite Tethers. Equations of Motion and Numerical Solution Algorithms for the Tether
P.E. Nacozy
Dept. of Aerospace Engrg. and Engrg. Mechanics, Univ. of Texas at Austin
Rept. No. NASA-CR-171777, 46 pp (Jan 31, 1984) N84-22598

KEY WORDS: Spacecraft components, Numerical methods

The equations of motion are developed for a perfectly flexible, inelastic tether with a satellite at its extremity. The tether is attached to a space vehicle in orbit. The tether is allowed to possess electrical conductivity. A numerical solution algorithm to provide the motion of the tether and satellite system is presented. The resulting differential equations can be solved by various existing standard numerical integration computer programs. The resulting differential equations allow the introduction of approximations that can lead to analytical, approximate general solutions. The differential equations allow more dynamical insight of the motion.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

85-40
Earthquake Energy Absorption in SDOF Structures
T.F. Zahrah, W.J. Hall
Agbabian Associates, 250 N. Nash St., El Segundo, CA 90245
ASCE J. Struc. Engrg., 110 (8), pp 1757-1772 (Aug 1984) 11 figs, 2 tables, 9 refs

KEY WORDS: Energy absorption, Earthquake resistant structures, Earthquake excitation, Inelastic materials

The energy absorption in, and the inelastic behavior of, simple structures during strong earthquake excitation are investigatetd. The purposes of the investigation are to evaluate the performance of simple structures during various types of ground motion, and to attempt to identify factors that influence structural deformation and damage. The amount of energy imparted to a structure and the amount of energy dissipated by inelastic deformations and damping are investigated. The displacement ductility and the number oif yield excursions and reversals experienced during the excitation are also discussed. Based on the amount of energy imparted to the structures, a possible effective motion criterion is defined.

85-41
Feasibility Evaluation of Base Isolation for the Aseismic Design of Structures
N.R. Vaidya, A.J. Eggenberger
D'Appolonia Consulting Engineers, Inc., Pittsburgh, PA
Rept. No. NSF/CEE-84001, 130 pp (1984) PB84-186717

KEY WORDS: Seismic design, Base isolation

The development of base isolation for use in seismic protection of building structures is examined and the base-isolated design philosophy is discussed. The shape, size, and number of bearings used to isolate a structure are evaluated in terms of the structure's aseismic design requirements. The equations of motion for structures of base-isolation bearings are described, along with procedures for the step-by-step integration of the nonlinear equations of motion. Three case studies are presented to illustrate the base-isolated response of structures. It is concluded that base isolation is most effective in reducing seismic forces on rigid structures, with fundamental frequencies in the range of about 3 to 10 Hz. It is recommended that variability of building material properties and the dynamic characteristics of the building be included in a probabilistic analysis to develop risk assessment for base-isolated designs.

85-42
Seismic Analysis of Piping with Nonlinear Supports
D.A. Barta, S.N. Huang, L.K. Severud
Westinghouse Hanford Co., Richland, WA
"Pressure Vessels and Piping: Design Technology -- 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 439-448, 13 figs, 6 tables, 8 refs

KEY WORDS: Snubbers, Piping systems, Nuclear power plants, Seismic analysis, Nonlinear theories

In the high temperature and seismic environment of a nuclear power plant, such as the Fast Flux Test Facility, mechanical type snubbing devices are used to restrain piping motions during seismic events. Results of time-history nonlinear seismic analysis for three sizes of pipelines on the whole piping system basis, incorporating snubber models based on test determined snubber characteristics, are presented.

85-43
Preliminary Evaluation of Waveguide Vibration Absorbers
E.E. Ungar, L.G. Kurzweil

Bolt Beranek and Newman, Inc., Cambridge, MA
Rept. No. BBN-5527, AFWAL-TR-83-3125, 58 pp (Jan 1984) AD-A140743

KEY WORDS: Vibration absorbers, Mechanical impedance

The loss factor contribution provided to a vibrating structure by an attached energy-absorbing system is analyzed in terms of the mechanical impedances of the structure and attached system. The driving-point impedance of an exponentially tapered semi-infinite beam is derived and is used to determine the parameters that govern the energy-absorption characteristics of flexural waveguide absorbers. Impedances measured on several preliminary candidate absorber configurations are reported, together with the loss factor contributions they provided for an experimental plate. Although these configurations were found not to exhibit the desired waveguide behavior, their measured loss factor contributions were found to be in good agreement with those predicted from their measured impedances. It is concluded that flexural waveguide absorbers indeed have the potential for providing significant damping. In order to achieve this effect, they must be impedance-matched to the structure that is to be damped. Absorber configurations need to be developed that exhibit the desired waveguide behavior in the frequency range of concern.

85-44
Vibration Control of Rotating Shaft with Self-Optimizing Support System
Y. Iwata, K. Nonami
Tokyo Metropolitan Univ., Setagaya-ku, Tokyo, Japan
Bull. JSME, 27 (228), pp 1306-1311 (June 1984) 15 figs, 2 refs

KEY WORDS: Supports, Tuning, Shafts, Critical speeds, Optimization

This paper proposes a new design concept of a self-optimizing support system for a rotating shaft. The purpose of this support system is to provide the self-tuning for the support stiffness such that the vibration of a rotating shaft usually occurs at the near antiresonance with changes of a rotating speed. The optimal tuning values of support stiffness are obtained by the on-line estimations of rotating angular velocities of a rotating shaft. The effect of the self-optimizing support system is proved by the tests of nonstationary responses for a fundamental rotor-shaft system.

TIRES AND WHEELS

85-45
On the Approach to Steady State for Frictional Contact under Moving Loads
J. Dundurs, A.K. Gautesen
Northwestern Univ., Evanston, IL 60201

J. Appl. Mech., Trans. ASME, 50 (4a), pp 783-788 (Dec 1983) 4 figs, 4 refs

KEY WORDS: Friction, Moving loads, Tire-wheel interaction

There is a class of problems involving frictional contact for which a steady state of slip is possible under moving loads. For instance, a tire is press-fitted on a wheel and loaded by forces that travel along its circumference and induce localized slip between the tire and the wheel. The steady state slip has been investigated before, but no estimates showing how quickly the steady state is approached are available. The present paper considers for this purpose a problem that can largely be reduced analytically. It involves two half spaces that are pressed together and sheared. The contact interface is locally pried apart by concentrated normal tractions which, after application, start to move. The moving normal forces induce localized separation and slip zones that travel along the interface. The analysis based on integral equations shows that the approach to steady state is relatively slow.

BLADES

85-46
Characteristics of Natural Frequencies

of Steam Turbine Blades (2nd Report, Influence of Disk on Vibration of Grouped Blades)
M. Shiga
Hitachi Ltd., Kandatsu, Tsuchiura, Ibaraki, Japan
Bull. JSME, 27 (228), pp 1203-1209 (June 1984) 5 figs, 7 refs

KEY WORDS: Turbine blades, Steam turbines, Natural frequencies, Rotatory inertia effects, Transverse shear deformation effects

A method of calculating the natural frequencies of the axial vibrations of steam turbine blades and thick disks is presented, and the natural frequencies of blades are calculated and compared with the measured values. It is found that the difference between the calculated and measured values is within 10 percent. The natural frequencies become higher at about 30 percent depending on the defaults of the rotary inertia and the shear deformation. The effect of rotary inertia is small, while that of shear deformation is large. The relationship between the number of nodal diameters and natural frequencies is made clear by calculation.

85-47
Finite Element Dynamic Analysis of Blade Shear Center Effects on Practical Bladed Discs
V. Karadag
Technical Univ. of Istanbul, Macka, Istanbul, Turkey
J. Sound Vib., 94 (2), pp 183-197 (May 22, 1984) 6 figs, 8 tables, 26 refs

KEY WORDS: Blades, Disks, Finite element technique

Dynamic characteristics of rotating and non-rotating practical bladed discs have been investigated by taking blade shear center effects into account. Both, thin or thick beam and plate theories, and the finite element method have been used in the analysis. The disc has been modeled by conforming sector disc elements, and the blades by classical thin beam and 18 degrees of freedom thick beam models. Shear center effects have been shown by comparing calculated values for different models and available calculated and experimental values obtained by others. It has been found that when these effects in the blade are high the bladed disc vibration characteristics can also be considerably changed.

BEARINGS

85-48
Influence of Surface Roughness and Its Orientation on Partial Elastohydrodynamic Lubrication of Rollers
J. Prakash, H. Czichos
Indian Inst. of Tech., Bombay, India
J. Lubric. Tech., Trans. ASME, 105 (4), pp 591-597 (Oct 1983) 6 figs, 1 table, 22 refs

KEY WORDS: Roller bearings, Lubrication, Elastohydrodynamic properties

In this paper, a complete solution for a rough, isothermal elastohydrodynamic line contact operating in the partial lubrication regime is presented. The semianalytical EHD line contact model developed recently is used in solving the coupled system of average Reynolds equation and the elasticity equation. The effects of various operating parameters and the roughness parameters are investigated with an emphasis on the outlet behavior. The results indicate that in the partial lubrication regime changes in the outlet may play an important role on the stability of elastohydrodynamic films.

85-49
Elastohydrodynamic Lubrication of Finite Line Contacts
A. Mostofi, R. Gohar
Imperial College, London SW7, UK
J. Lubric. Tech., Trans. ASME, 105 (4), pp 598-604 (Oct 1983) 10 figs, 14 refs

KEY WORDS: Roller bearings, Lubrication, Elastohydrodynamic properties

In this paper, a numerical solution to the elastohydrodynamic lubrication (EHL) problem is presented for a cy-

lindrical roller with axially profiled ends, rolling over a flat plane. Convergence was obtained for moderate load and material parameters (glass, steel, and a mineral oil). Isobars, contours, and section graphs, show pressure variation and film shape. Predictions of film thickness compare favorably with experiments using the optical interference method, as well as with other theoretical results for an infinite line contact, or an ellipse having a long slender aspect ratio. The maximum EHL pressure occurs near the start of the profiling and can exceed pressure concentrations there predicted by elastostatic theory.

85-50
A Vibration Analysis of a Bearing/Cartridge Interface for a Fretting Corrosion Study
K.B. Elliott, H.H. Mabie, M.J. Furey, L.D. Mitchell
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061
J. Lubric. Tech., Trans. ASME, 105 (4), pp 518-525 (Oct 1983) 8 figs, 5 tables, 20 refs

KEY WORDS: Ball bearings, Fretting corrosion

The relative motion between a ball bearing outer race and the bearing's cartridge was investigated. The investigation was part of a larger program, the objective of which was to examine the important parameters influencing fretting corrosion in rolling element bearings. The bearing examined was a 320 size, deep grooved, ABEC 7 ball bearing used in a ship board motor-generator unit. Three axes of acceleration signatures were simultaneously recorded from the outer race and cartridge. These acceleration signatures were Fourier transformed, averaged, and integrated twice to obtain displacement frequency spectrums. Corresponding displacements were vectorially subtracted to produce the relative motion between the outer race and the cartridge. Two load cases (0 and 100 percent load) and two frequency ranges (15 to 500 Hz to 10 kHz) are examined. The resulting relative motion spectrums were complex with the bearing's forcing frequencies dominating the spectrums below 250 Hz and rotor imbalance causing the highest spectral component of relative displacement.

85-51
Centrifugal Effects in Misaligned Hydrostatic Thrust Bearings
Z.S. Safar
Cairo Univ., Cairo, Egypt
J. Lubric. Tech., Trans. ASME, 105 (4), pp 621-624 (Oct 1983) 8 figs, 7 refs

KEY WORDS: Thrust bearings, Centrifugal forces, Alignment

An analysis is conducted and solutions are provided for the effect of centrifugal forces on hydrostatic misaligned thrust bearings. The results show that centrifugal forces reduce considerably the load capacity, the friction torque and increase the lubricant flow rate. It is found that the effect of centrifugal forces is decreased as tilting of the bearing is increased.

85-52
An Influence of Centrifugal Force on the Performances of Thermo-hydrodynamic Turbulent Thrust Bearings
H. Hashimoto, S. Wada, Y. Murayama
Tokai Univ., Hiratsuka-shi, Kanagawa, Japan
Bull. JSME, 27 (228), pp 1230-1236 (June 1984) 11 figs, 11 refs

KEY WORDS: Thrust bearings, Centrifugal forces

This paper presents a study on the influence of a centrifugal force on the performance characteristics of thermo-hydrodynamic turbulent force on the performance characteristics of thermo-hydrodynamic turbulent thrust bearings. By applying a lubrication equation and an energy equation to plane inclined, sector shaped thrust bearings, performance characteristics are evaluated. The analysis shows that the centrifugal force affects significantly the film pressure and the load carrying capacity but insignificantly the friction torque and the

temperature rise. The analytical results are compared with the experimental ones measured on the thrust bearing of 150 mm diameter with four sector shaped pads lubricated with spindle oil and water. The analytical results agree well with the experimental ones.

85-53
An Experimental Investigation of the Stability of Externally Pressurized Gas-Lubricated Porous Thrust Bearings
H.S. Chang, Z.S. Wang, D.C. Sun
Beijing Inst. of Aeronautics and Astronautics, Beijing, People's Rep. of China
J. Lubric. Tech., Trans. ASME, 105 (4), pp 630-637 (Oct 1983) 7 figs, 9 refs

KEY WORDS: Thrust bearings, Gas bearings

The stability characteristics of the porous disk thrust bearing was studied experimentally and compared with a theoretical prediction. The discrepancy between them was found to be small in the low supply pressure region and large in the high supply pressure region. At instability the pressure in the plenum was found to oscillate in response to the oscillation of the upper thrust plate. Thus the plenum volume emerged as an important factor affecting stability. In addition to the porous disk bearing, two other types of thrust bearings, viz, the plain disk with a porous insert and the plain disk with a recess and orifice restriction were also included in the study. The three types of bearings were compared with reference to their stability. Within the same range of the gas flow rate, the porous insert bearing displayed an equal or larger region of stable operation in comparison with the orifice bearing. Besides, the porous insert bearing exhibited a feature which could simplify its construction and make its application very attractive.

85-54
Analysis of Gas Lubricated Compliant Thrust Bearings
H. Heshmat, J.A. Walowit, O. Pinkus
Mechanical Technology Inc., Latham, NY 12110
J. Lubric. Tech., Trans. ASME, 105 (4), pp 638-646 (Oct 1983) 18 figs, 3 tables, 5 refs

KEY WORDS: Gas bearings, Foil bearings, Thrust bearings

This work is concerned with an evaluation of the performance of a gas thrust bearing using what amounts to a spring supported compliant foil as the bearing surface. To enhance the load capacity of such a device, the leading portion of the foil is given an appropriate converging geometry. The paper offers an analytical investigation of the elastohydrodynamics of the compliant foil bearing, and the effects that the various structural and operational variables have on bearing behavior.

85-55
Analysis of Gas-Lubricated Foil Journal Bearings
H. Heshmat, J.A. Walowit, O. Pinkus
Mechanical Technology, Inc., Latham, NY 12110
J. Lubric. Tech., Trans. ASME, 105 (4), pp 647-655 (Oct 1983) 17 figs, 5 tables, 5 refs

KEY WORDS: Gas bearings, Journal bearings, Foil bearings

This work is concerned with an evaluation of the performance of a gas journal bearing using a spring supported compliant foil as the bearing surface. The analysis, conducted for both single and multipad configurations, is concerned with the effects that the various structural, geometric, and operational variables have on bearing behavior. Following the solution of the relevant differential equation, tabular or graphical solutions are provided for a range of relevant geometric and operational parameters. The solutions include values of the colinear and cross-coupled spring coefficients due to both structural and hydrodynamic stiffness. Desirable design features with regard to start of bearing arc, selection of load angle, number of pads and degree of compliance are discussed.

85-56
On a Controlling Method of Amplitude and Frequency of Self-Excited Vibration in an Externally Pressurized, Recessed-type Gas Bearing
A. Mori, S. Matsumoto, H. Mori
Kyoto Univ., Sakyo-ku, Kyoto 606, Japan
Bull. JSME, 27 (228), pp 1224-1229 (June 1984) 12 figs, 3 refs

KEY WORDS: Gas bearings, Self-excited vibrations, Vibration control

A self-excited vibration induced in an externally pressurized, recessed-type gas bearing is applicable to a pneumatic vibrator. An orifice and a chamber connected to a recess produce a self-excited vibration describing a limit cycle, the amplitude and frequency of which vary with the area of the orifice and the volume of the chamber. It is proposed, utilizing such a phenomenon, to provide the recess with an orifice of variable area and a chamber of variable volume as a powerful method to control the amplitude and frequency of the vibration. The controlling ability of the proposed method is discussed theoretically and experimentally.

85-57
The Role of Cavitation in Whirl Instability in a Rotor Bearing. 1. The π-Film Model
J. Brindley, L. Elliott, J.T. McKay
Univ. of Leeds, Leeds, UK LS2 9JT
J. Appl. Mech., Trans. ASME, 50 (4a), pp 877-885 (Dec 1983) 7 figs, 11 refs

KEY WORDS: Fluid film bearings, Whirling, Cavitation

Dynamically loaded rotor bearings are frequently observed to perform whirling motions, in which the center of the rotor describes some sort of closed orbit. In this paper the role of cavitation of the lubricant in enabling fluid forces alone to drive such stable orbits for certain ranges of parameter values is demonstrated. For other parameter values cavitation may actually enhance the instability always associated with the effects of fluid forces in a full-film bearing.

85-58
The Role of Cavitation in Whirl Instability in a Rotor Bearing: 2. Effect of Oil Inlet Position and Supply Pressure
J. Brindley, L. Elliott, J.T. McKay
Univ. of Leeds, Leeds, UK LS2 9JT
J. Appl. Mech., Trans. ASME, 50 (4a), pp 886-890 (Dec 1983) 7 figs, 5 refs

KEY WORDS: Fluid film bearings, Whirling, Cavitation

Whirl orbits have been calculated for a cavitated rotor bearing in which the cavity is assumed to form at an oil inlet groove and occupy the region in which subambient pressure is predicted from the equations of motion. Variations in position of the inlet groove and in the oil supply pressure have a profound influence on the behavior of the journal, largely through the variations in cavity size and position that are produced.

FASTENERS

85-59
On the Measurement of the Coupling Loss Factor of Structural Connections
B.L. Clarkson, M.F. Ranky
University College of Swansea, Singleton Park, Swansea SA2 8PP, Wales
J. Sound Vib., 94 (2), pp 249-261 (May 22, 1984) 19 figs, 1 table, 10 refs

KEY WORDS: Joints, Statistical energy analysis

Previous attempts to measure the coupling loss factor of structural joints have shown that the results are very sensitive to small errors in the measurements. As the energy transfer at the joints is usually smaller than the dissipation loss in a structural member, the direct measurement of the coupling loss factor is very difficult. In this paper a development of the in situ measurement method used by Bies and Hamid is described. An iteration technique is used to give estimates of the coupling loss factor and individual dissipation loss factors which provide the best fit to the experimental data. Results for a

simple two plate configuration compare well with theory for the coupling loss and independent measurements for the dissipation loss factors. The method is then applied to the junction of a plate and cylinder where the coupling loss is somewhat lower than that of the two plate junction.

85-60
Effects of Anomalous Rotor Joints on Turbomachine Dynamics
N. Klompas
General Electric Co., Schenectady, NY 12345
J. Engrg. Power, Trans. ASME, 105 (4), pp 927-934 (Oct 1983) 13 figs, 9 refs

KEY WORDS: Joints, Rotors, Turbomachinery, Unbalanced mass response

Mechanisms simulating rotor joint restoring moments different from the common axisymmetric elastic hinge are derived. Their effects on the dynamics of a complete turbomachine are calculated by impressing equivalent perturbing moments. A mechanism for locking subsynchronous whirl to a fractional frequency is described and supporting experimental observations are discussed. Sample analysis shows the possibility of self-sustained synchronous whirl due to preload asymmetry.

85-61
Fatigue Tests of Weathered Welded Joints
K. Yamada, Y. Kikuchi
Nagoya Univ., Chikusaku, Nagoya 464, Japan
ASCE J. Struc. Engrg., 110 (9), pp 2164-2177 (Sept 1984) 10 figs, 9 tables, 11 refs

KEY WORDS: Welded joints, Steel, Fatigue tests, Experimental data

The fatigue behavior of weathered welded specimens of weathering steel (JIS SMA50) and structural steel (SM50) was investigated. Sixty-six stiffener specimens and 62 gusset specimens were tested under constant amplitude stress cycle after 2 and 4 yr of atmospheric exposure without paint. The 2-yr and 4-yr weathered specimens showed no reduction of fatigue life when compared with non-weathered specimens. An additional 10 stiffener specimens were cut from web of an actually used weathering steel bridge. They were weathered for about 5.5 yr, and showed fatigue behavior equivalent to that of the 4-yr weathered stiffener specimens.

85-62
Damage Assessment of Mechanically Fastened Joints in the Small Crack Size Range
J.L. Rudd, J.N. Yang, S.D. Manning, B.G.W. Yee
Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH
U.S. National Congress of Applied Mechanics, Proc. of the 9th, Cornell Univ., Ithaca, NY, June 21-25, 1982, ASME, 1982, pp 329-338, 12 figs, 37 refs

KEY WORDS: Joints, Fatigue life, Crack propagation

A statistically-based methodology is described and illustrated for quantifying the extent of damage due to cracking in mechanically fastened joints. A statistical model is described for establishing the initial fatigue quality of fastener holes in terms of time-to-crack-initiation and equivalent initial flaw size concepts. With the proposed model, the initial fatigue quality can be quantified for strructural details without considering small crack growth kinetics. Essential features of the model and utilization procedures are described and emphasized. A simplified analysis is presented for a complex lap shear specimen subjected to a B-1 bomber load spectrum to illustrate the important features and output of the methodology. The analytical results are compared with experimental data.

85-63
Shear Links in Eccentrically Braced Frames
J.O. Malley, E.P. Popov
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ASCE J. Struc. Engrg., 110 (9), pp 2275-2295 (Sept 1984) 15 figs, 2 tables, 18 refs

KEY WORDS: Joints, Frames, Braces, Seismic design

Eccentrically braced steel framing in seismic applications can provide high elastic stiffness and large inelastic energy dissipation capacity. The performance of this framing system depends to a great extent on the behavior of short active link sections of the beams. The results of an experimental investigation of the effects of inelastic loading history, connection details, and web stiffener details on active link behavior are presented. The test results are then evaluated using energy dissipation as the basic parameter. A design procedure for active links which yield primarily in shear is then outlined. This procedure includes recommendations on the determination of structural configuration, member sizes, link connection details, and web stiffener details. Suggested connection and stiffener details are illustrated.

85-64
Seismic Response of Composite Shear Connections
N.M. Hawkins, D. Mitchell
Univ. of Washington, Seattle, WA
ASCE J. Struc. Engrg., 110 (9), pp 2120-2136 (Sept 1984) 16 figs, 4 tables, 10 refs

KEY WORDS: Studs, Fasteners, Seismic response

Four different failure modes, stud shearing, concrete pullout, rib shearing and rib punching are described for metal deck stud shear connections. Equations for predicting the strengths associated with those failures are derived. Behavioral comparisons are made between companion specimens subjected to monotonic and reversed cyclic loading. It is shown that the type of failure greatly influences the strength, ductility and reversed cyclic loading response. The benefits of using larger stud-spacings, staggering of the studs, larger rib widths and ribs parallel to the direction of applied shear are demonstrated.

85-65
Cyclic In-Plane Buckling of Double Angle Bracing
A. Astaneh-Asl, C.S. Goel
Univ. of Oklahoma, Norman, OK 73019
ASCE J. Struc. Engrg., 110 (9), pp 2036-2055 (Sept 1984) 21 figs, 1 table, 25 refs

KEY WORDS: Braces, Frames, Dynamic buckling, Cyclic loading, Seismic response

The behavior of double-angle bracing members subjected to in-plane buckling due to severe cyclic load reversals is investigated. Eight full-size test specimens made of back-to-back double angle sections, connected to the end gusset plates by fillet welds or high strength bolts, were tested under large amplitude cyclic loading. Some test specimens, designed by current code procedures showed failures during early cycles of loading. New design procedures are proposed to improve the ductility and energy dissipation capacity of double angle bracing members and their connections to withstand severe cyclic loadings.

LINKAGES

85-66
Critical Running Speeds and Stability of High-Speed Flexible Mechanisms
W.L. Cleghorn, B. Tabarrok, R.G. Fenton
Univ. of Manitoba, Winnipeg, Manitoba, Canada R3T 2N2
Mech. Mach. Theory, 19 (3), pp 307-317 (1984) 7 figs, 2 tables, 14 refs

KEY WORDS: Critical speeds, Linkages, Stability

A procedure is presented for determining critical running speeds of flexible mechanisms. In this procedure, the flexible links are represented by finite elements. Governing equation components, throughout a cycle, are representetd by truncated Fourier series. By comparing harmonic terms, the problem of determining the critical running speeds for a physically undamped mechanism is reduced to that

of an eigenvalue problem, and a discrete set of critical running speeds is found. A proposed method of determining stable and unstable regions of input speed operation for a flexible mechanism is also presented.

VALVES

85-67
Flow-Induced Vibration in Safety Relief Valves: Design and Trouble-Shooting Methods
R.M. Baldwin, H.R. Simmons
SWRI, San Antonio, TX
ASME Paper No. 84-PVP-8

KEY WORDS: Valves, Power plants, Fluid-induced excitation

Pulsation and vibration data recorded from several valves in power plant steam service are presented for comparison of stable and unstable configurations. Based on this data, a rational design procedure utilizing the relationship among Strouhal number, Mach number, and stub dimensions has been developed to eliminate an existing problem or to prevent one in new piping systems.

SEALS

85-68
Preliminary Results on the Abradability of Porous, Sintered Seal Material
J. Wolak, A.F. Emery, S. Etemad, S.R. Choi
Univ. of Washington, Seattle, WA 98195

J. Lubric. Tech., Trans. ASME, 105 (4), pp 576-584 (Oct 1983) 11 figs, 1 table, 7 refs

KEY WORDS: Seals, Blades, Rubs

Results are presented for the case of titanium blade specimens with bare tips rubbing at 100 m/s against specimens of abradable nickel-chromium seal material moving toward rotating blades at 0.0125 mm/s or at 0.025 mm/s. Using a two component dynamometer, the normal force of the rub interaction was measured and the shear component estimated. The elastoplastic properties of the seal material have been determined. These parameters as well as the rigidity of the rub tester system are considered in conjunction with those affecting the accuracy of the measurement of the forces arising at the blade-seal interface. The average and the "local instantaneous" temperatures of the seal specimen and the temperature of the blade tip surface during rubbing are presented as functions of time. A seal densification factor is defined and its functional relationships with contact force components, temperature, wear ratio and blade tip abrading capability are indicated.

STRUCTURAL COMPONENTS

BEAMS

85-69
Hysteretic Behavior of RC Beams
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ASCE J. Struc. Engrg., 110 (9), pp 2073-2084 (Sept 1984) 12 figs, 12 refs

KEY WORDS: Beams, Reinforced concrete, Hysteretic damping

A mechanical model for the cross section of a reinforced concrete beam is proposed. Attention is focused on the local phenomena relating to the cross section, while the phenomena relating to the beam element to which the section belongs is ignored. In particular the concrete fracturing mechanism and the slippage and yielding of steel are considered, while the smeared damage of concrete are not taken explicitly into account.

85-70
Transient Response of Timoshenko Beams with Discontinuities of Cross-Section
M.M. Al-Mousawi
The City Univ., London, UK
Intl. J. Mech. Sci., 26 (4), pp 277-292 (1984) 14 figs, 23 refs

KEY WORDS: Beams, Timoshenko theory, Flexural vibration, Transient response

Based on the Timoshenko beam theory, flexural elastic wave propagation in beams is analyzed. The method of characteristics is used for the numerical solution of the problem. The effect of reflections in finite beams with discontinuities of cross-section is considered. Stability and convergence of the numerical solution are discussed.

CYLINDERS

85-71
Vortex Excited Oscillation of a Circular Cylinder in a Uniform Flow
M. Shirakashi, S. Ueno, Y. Ishida, S. Wakiya
Technological Univ. of Nagaoka, Kamitomioka-cho 1603-1, Nagaoka, Niigata, Japan
Bull. JSME, 27 (228), pp 1120-1126 (June 1984) 18 figs, 6 refs

KEY WORDS: Circular cylinders, Fluid-induced excitation, Vortex shedding

Effects of a yaw angle on the vortex shedding frequency from a fixed circular cylinder were examined using a wind tunnel. Oscillations of an elastically supported cylinder whose motion was confined normal to its axis and the flow were investigated. The cosine law was confirmed to be applicable to the larger value of Reynolds number and/or the yaw angle for the vortex shedding frequency from a fixed cylinder. For an elastically supported cylinder a purely translational mode oscillation was observed at a low velocity.

COLUMNS

85-72
Stochastic Earthquake Response of Tapered Column
T.Y. Shih, Y.C. Chen
Memorex Corp., MS 14-49, San Tomas at Central Expressway, Santa Clara, CA 95052
ASCE J. Engrg. Mech., 110 (8), pp 1185-1210 (Aug 1984) 26 figs, 1 table, 27 refs

KEY WORDS: Columns, Earthquake response, Stochastic processes

This paper presents a stochastic analysis of a tapered column subjected to gravity as well as horizontal and vertical earthquake accelerations. The normal mode approach is used. The approach considers the effect of both nonuniformity in column configuration and axial loading on mode shapes and natural frequencies. The earthquake accelerations are modeled as nonstationary Gaussian random processes with either white or non-white power spectra. This allows the statistical moments of column responses to be solved from a set of first order ordinary differential equations derived from the theory of Markov process. Both time histories of responses and spatial distribution of maximum responses along the elevation of the column are presented. Exact analytical sequences can be applied to handle problems of nonuniform columns.

PLATES

85-73
Large Amplitude Free Vibrations of Square Plates of Variable Thickness
S.K. Ghosh
Jalpaiguri Government Engrg. College, Jalpaiguri 735101, W. Bengal, India
J. Sound Vib., 94 (2), pp 263-266 (May 22, 1984) 1 table, 6 refs

KEY WORDS: Plates, Free vibration, Variable cross section, Large amplitudes

The large amplitude free vibrations of a simply supported square plate of linearly varying thickness have been investigated.

85-74
Natural Vibrations of Laminated Anisotropic Plates
J.N. Reddy, T. Kuppusamy
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061
J. Sound Vib., 94 (1), pp 63-69 (May 8, 1984) 1 fig, 4 tables, 20 refs

KEY WORDS: Plates, Anisotropy, Laminates, Natural frequencies, Finite element technique

This paper contains a description of the three-dimensional elasticity equations and the associated finite element model for natural vibrations of laminated rectangular plates. The numerical results for natural frequencies are compared with those obtained by a shear deformable plate theory. A number of cross-ply and angle-ply rectangular plates are analyzed for natural frequencies. For relatively thick plates, the plate element predicts frequencies higher than those predicted by the 3-D element.

85-75
Free Vibration of a Solid Plate of Arbitrary Shape Lying on an Arbitrarily Shaped Ring Support
K. Nagaya
Gunma Univ., Kiryu, Gunma 376, Japan
J. Sound Vib., 94 (1), pp 71-85 (May 8, 1984) 4 figs, 6 tables, 22 refs

KEY WORDS: Plates, Ring springs, Natural frequencies

This paper is concerned with a method for solving problems of vibrating plates of arbitrary shape lying on arbitrarily shaped inner ring supports. To treat the inner ring support, the reaction force of the support is assumed to be an external unknown force. The exact solution of the equation of motion in polar co-ordinates is applied. The boundary conditions along the edge and the support are satisfied directly by means of the Fourier expansion collocation method which has been developed in the author's previous reports. Numerical calculations have been carried out for a solid polygonal plate on an annular ring support and a solid circular plate on an elliptical ring support.

85-76
Effects of Geometric Imperfections on Vibrations of Biaxially Compressed Rectangular Flat Plates
D. Hui, A.W. Leissa
Ohio State Univ., Columbus, OH 43210
J. Appl. Mech., Trans. ASME, 50 (4a), pp 750-756 (Dec 1983) 7 figs, 1 table, 15 refs

KEY WORDS: Plates, Rectangular plates, Geometric imperfection effects, Vibration response

This paper deals with the effects of geometric imperfections on the vibration frequencies of simply supported flat plates under in-plane uniaxial or biaxial compression. The analysis is based on a solution of the nonlinear von Karman equations for finite deflections, incorporating the influence of an initial geometric imperfection. It is found that significant increase in the vibration frequencies may occur for imperfection amplitude of the order of a fraction of the plate thickness, even in the absence of in-plane forces.

85-77
Long-Time Response of a Finite Cantilever Plate to Antisymmetric Dynamic Surface Loading
A.A. Lotfy, H.H.E. Leipholz
Univ. of Waterloo, Waterloo, Ontario, Canada
J. Sound Vib., 94 (2), pp 161-173 (May 22, 1984) 2 figs, 7 refs

KEY WORDS: Cantilever plates, Transient response

This paper treats the transient response of a finite, isotropic, homogeneous, elastic cantilever plate in a state of plane strain to an antisymmetric surface line load, which is

assumed to be a step function in time. The corner stress singularities are considered in the evaluation of the stress distribution at the fixed end. Then, the near field solution is found by means of asymptotic expansion. Moreover, the transverse displacement along the plate is obtained in the traveling wave form as well as in the vibrational one, which is evaluated numerically and discussed. Engineering methods in which a "dynamic load factor" is used in conjunction with the static solution tend to underestimate the values of the deflections beyond the point of load up to the free end of the cantilever plate.

85-78
Long-Time Response of Finite Cantilever Plates to Dynamic Surface Loadings
A.A. Lotfy, H.H.E. Leipholz
Univ. of Waterloo, Waterloo, Ontario, Canda
J. Sound Vib., 94 (2), pp 175-182 (May 22, 1984) 7 figs, 12 refs

KEY WORDS: Cantilever plates

This paper is concerned with long-time analysis of the response of finite, isotropic, homogeneous, elastic cantilever plates to different dynamic surface loadings while the plate is assumed to be in a state of plane strain. The analysis is based on a method given by J. Miklowitz for solving non-separable waveguide problems in which an entirety condition is used on the solution. The effect of the material properties on the stress singularities at the corners of the fixed end is considered for a calculation of the singularity exponent for a realistic engineering material. Moreover, a change of the loading function is considered in the general solution of the problem. It is concluded that, for the finite plate, the results calculated for antisymmetric loading are good approximations to the unsymmetric case. This work may be considered as a step towards the assessment of the importance of stress wave propagations in finite plates, as such waveguides have some practical significance in structural engineering.

85-79
The Driving-Point Impedance of a Plate with an Attached Subsystem
Z.C. Zhang, B.L. Clarkson
Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton S09 5NH, UK
J. Sound Vib., 94 (2), pp 235-247 (May 22, 1984) 8 figs, 7 refs

KEY WORDS: Plates, Mechanical impedance

A general expression for the driving-point impedance of an infinite thin plate with an attached subsystem some distance from the driving point is derived. The analysis is based upon the receptance method and the reciprocal theorem. As an example, an infinite plate with an attached rigid circular cylinder is examined. Results are compared with experiments on a finite plate and good agreement in the frequency average sense is obtained. It is shown from the results that the effects of the attached mass and the rotational inertia on the driving-point impedance are mainly in the region of the near field. The effect of the shape of the contact area was studied in a second set of experiments. An equivalent circle is proposed to represent a square contact area.

85-80
Vibrations of an Initially Stressed Transversely Isotropic Circular Thick Plate
Lien-Wen Chen, Ji-Liang Doong
National Cheng-Kung Univ., Tainan, Taiwan, China
Intl. J. Mech. Sci., 26 (4), pp 253-263 (1984) 7 figs, 1 table, 19 refs

KEY WORDS: Plates, Equations of motion, Transverse shear deformation effects, Rotatory inertia effects,

Equations of motion for a transversely isotropic circular thick plate in a general state of nonuniform initial stress where the effects of transverse shear and rotary inertia are included are derived. The natural frequencies of axisymmetric clamped plates and simply supported plates subjected to initial stresses are investigated. The initial stress is taken to be a combination of a pure bending stress plus

an extensional stress in the plane of the plate. These equations are solved by the Galerkin method. The effects of various parameters on the natural frequencies are studied.

85-81
Nonlinear Vibration of Generally Laminated Anisotropic Thick Plates
K.S. Sivakumaran, C.Y. Chia
Univ. of Calgary, Calgary, Alberta T2N 1N4, Canada
Ing. Arch., 54 (3), pp 220-231 (1984)
6 figs, 1 table, 23 refs

KEY WORDS: Plates, Layered materials, Hamiltonian principle, Equations of motion, Transverse shear deformation effects

Nonlinear equations of motion of generally laminated anisotropic plates are derived by use of Hamilton's principle. The effects of transverse shear and rotatory inertia are included in the analysis. The equations of motion so obtained readily reduce to those obtained in a recent nonlinear theory of anisotropic plates including transverse shear and rotatory inertia and to the dynamic von Karman equations of plates. Based on the Galerkin procedure and principle of harmonic balance approximate solutions to the governing equations of generally laminated rectangular plates are formulated for various boundary conditions.

SHELLS

85-82
Blast Loading of a Spherical Container Surrounded by an Infinite Elastic Medium
L.A. Glenn, R.E. Kidder
Univ. of California, Livermore, CA 94550
J. Appl. Mech., Trans. ASME, 50 (4a), pp 723-726 (Dec 1983) 4 figs, 4 refs

KEY WORDS: Spherical shells, Containers, Blast loads

Closed-form solutions are derived for the response of a spherical elastic shell, surrounded by a different elastic medium of infinite extent, and subjected to Heaviside or impulsive loading. The results are compared with earlier solutions in which the surrounding medium was a fluid. The importance of interfacial separation is also investigated by comparing the impulsive loading results with finite difference calculations.

RINGS

85-83
Vibrations of a Thick-Walled Pipe or a Ring of Arbitrary Shape in Its Plane
K. Nagaya
Gunma Univ., Kiryu, Gunma 376, Japan
J. Appl. Mech., Trans. ASME, 50 (4a), pp 757-763 (Dec 1983) 7 figs, 2 tables, 13 refs

KEY WORDS: Rings, Pipes

This paper is concerned with a method for solving in-plane vibration problems of thick-walled pipes and rings of arbitrary shape. The solution to the equation of motion based on the theory of elasticity under the plane-strain assumption is obtained exactly by using polar coordinates. Numerical calculations have been carried out for a thick elliptical ring, a rectangular ring with rounded corners, and a rectangular ring with a circular inner boundary. To discuss the accuracy of the present analysis, the results of a thick circular ring have also been calculated, and the present results are compared with the previously published ones.

PIPES AND TUBES

85-84
Mechanisms of the Generation of External Acoustic Radiation from Pipes Due to Internal Flow Disturbances
M.P. Norton, M.K. Bull

Univ. of Western Australia, Nedlands, Western Australia 6009, Australia
J. Sound Vib., 94 (1), pp 105-146 (May 8, 1984) 27 figs, 30 refs

KEY WORDS: Pipes, Sound waves, Wave generation, Turbulence

Extensive spectral measurements of the internal wall pressure fluctuations, pipe wall acceleration, and external acoustic radiation, due to the disturbance of a fully developed turbulent air flow in a pipe are presented. The measurements were made at sufficient distances downstream of the disturbance for an undisturbed hydrodynamic regime to be re-established. The only remaining disturbance was a superimposed internal acoustic field radiated from the disturbance. This internal acoustic field comprises, in general, both plane wave and higher order acoustic modes, although its detailed character depends on the particular characteristics of the individual fittings. It gives rise to increases in pipe wall vibration and external radiation, by large amounts in the cases of the more severe disturbances, over those due to undisturbed turbulent pipe flow. The background theory of pipe wall response and radiation which provides the framework for interpretation of the experimental results and identification of sound generation mechanisms is also presented.

85-85
Results from Dynamic Tests and Analyses of a Medium Diameter LMFBR in Piping System
G.A. Schott, G.M. Hulbert, C.F. Herberling, II
Westinghouse Electric Corp., Madison, PA
ASME Paper No. 84-PVP-19

KEY WORDS: Piping systems, Dynamic tests

Presented are results and observations from dynamic tests and analyses performed on a 0.20 m (8 in.) dia., thin walled piping system. The piping system is a scaled representation of an LMFBR large diameter piping loop. Prototypic piping restraints were employed, including mechanical snubbers, rigid struts, pipe hangers, and non-integral pipe clamps.

85-86
Equipment Modelling in Piping Dynamic Analysis
L.H. Geraets, P. Detroux
Tractional, Brussels, Belgium
ASME Paper No. 84-PVP-39

KEY WORDS: Piping systems, Equipment-structure interaction

Piping systems are usually connected to equipment; the equipment flexibility yields another type of transfer function which in turn influences significantly the response spectra to be used as load data in piping analysis. Two techniques have been proposed to take this effect into account: generation of nozzle response spectra; and introduction of simplified equipment models in the piping models.

85-87
Vibration of Piping Systems Containing a Moving Medium by the Transfer Matrix Method
C.W.S. To, V. Kaladi
Univ. of Calgary, Alberta, Canada
ASME Paper No. 84-PVP-30

KEY WORDS: Piping systems, Vibration analysis, Transfer matrix method

A transfer matrix method is proposed for the vibration analysis of complicated piping networks involving bends, piping components of various diameters, and lumped masses such as valves with a moving medium. The proposed approach is much more economical to use than the versatile finite element method, and can be easily implemented in a microcomputer.

85-88
Hydroelastic Response of a Circular Tube in Eccentric Annular Flows
W.H. Lin, J.A. Jendrzejczyk
Argonne National Lab., Argonne, IL 60439

J. Sound Vib., 94 (2), pp 289-298 (May 22, 1984) 11 figs, 1 table, 17 refs

KEY WORDS: Tubes, Fluid-induced excitation, Natural frequencies

This paper describes an experimental study of the hydroelastic response of a tube located concentrically and eccentrically, respectively, in a circular water-flow channel. Acceleration components in two orthogonal directions were measured at the midpoint of the test element by using a pair of accelerometers. The investigation included determination of natural frequencies, damping factors, rms displacements, and the variations of these dynamic quantities with eccentricity and mean axial flow velocity. The experimental data were processed into statistical forms, including power spectral density function and root-mean-square values. The results show that the natural frequency of the tube shifts as the eccentricity or flow velocity increases. The damping in flowing water is greater than that in stationary water, and increases with increasing flow velocity and eccentricity. The rms displacement increases as the eccentricity and/or flow velocity increases.

85-89
Heat Exchanger Tube Vibrations. 1970 - May, 1984 (Citations from the Engineering Index Data Base)
NTIS, Springfield, VA
102 pp (June 1984) PB84-866888

KEY WORDS: Tubes, Heat exchangers, Vibration analysis, Bibliographies

This bibliography contains citations concerning design, fabrication, and vibration studies of heat exchanger tubes. Basic excitation mechanisms of tube vibrations, effect of heat exchanger configurations, preoperational testing of tubes, and vibration detection techniques are discussed. Model studies and computer simulation techniques are presented. This updated bibliography contains 144 citations, 24 of which are new entries to the previous edition.

85-90
An Acoustic Evaluation of Circumferentially Segmented Duct Liners
W.R. Watson
NASA Langley Res. Ctr., Hampton, VA
AIAA J., 22 (9), pp 1229-1233 (Sept 1984) 9 figs, 3 tables, 7 refs

KEY WORDS: Ducts, Linings, Acoustic absorption

An evaluation of circumferentially segmented duct liners is performed by comparing attenuations of optimized segmented and uniform liners for a range of frequencies and source structures. Broadband suppression and the effects of changes to input modal structure are explored in these comparisons. Credence in the theoretical model was obtained by comparing predictions to results of a carefully controlled experiment performed on the Langley Spinning Mode Synthesizer Facility. Excellent agreement was obtained in these comparisons. It is shown that for the lower order spinning mode sources, the optimum segmented liner degenerates into an optimum uniform liner so that no increased suppression of the segmented liner over the uniform liner is obtained. In contrast, predicted results show that the optimized segmented liner is more effective than the optimized uniform liner for the higher order spinning mode sources with a hard wall admittance variation. Results indicate the segmented liner has better broadband performance with suppression characteristics that are particularly sensitive to the input modal structure when compared to that of the uniform liner. It is concluded that the greatest potential benefit of segmented liners is at cut-on mode cutoff frequencies and that these benefits are attained despite reductions in the total amount of liner treatment of 50%.

85-91
Two-Dimensional Acoustic Field in a

Nonuniform Duct Carrying Compressible Flow
K. Uenishi, M.K. Myers
George Washington Univ., Hampton, VA
AIAA J., 22 (9), pp 1242-1248 (Sept 1984) 7 figs, 5 refs

KEY WORDS: Ducts, Sound waves, Wave propagation

An analytical/numerical linear acoustic solution in a nonuniform two-dimensional duct carrying a compressible mean flow is developed. A quasi-one-dimensional mean flow model is employed together with a consistent expression for the cross-flow velocity. The acoustic solution is obtained using the wave envelope method. Numerical results are compared with those of an existing wave envelope solution which uses a more general mean flow model that includes a thin boundary layer. The results suggest that a thin boundary layer in the flow model may be of minor influence on the sound field in many cases of practical interest.

85-92
Uniform Asymptotic Approximations for Duct Acoustic Modes in a Thin Boundary-Layer Flow
M.K. Myers, S.L. Chuang
George Washington Univ., Hampton, VA
AIAA J., 22 (9), pp 1234-1241 (Sept 1984) 1 fig, 5 tables, 7 refs

KEY WORDS: Ducts, Sound waves, Wave propagation

Analytical approximations for the acoustic modes in a duct carrying a uniform core flow with a thin shear layer at the walls are developed using the method of matched asymptotic expansions. Both two-dimensional and cylindrical duct propagation are considered. Numerical results for eigenvalues calculated using the theory are presented for the two-dimensional problem and compared with results from earlier analyses. It is found that the new approximations yield a significant increase in accuracy.

85-93
An Improved Impulse Method for Studies of Acoustic Transmission in Flow Ducts with Use of Signal Synthesis and Averaging of Acoustic Pulses
M. Salikuddin, K.K. Ahuja, W.H. Brown
Lockheed-Georgia Co., Marietta, GA 30063
J. Sound Vib., 94 (1), pp 33-61 (May 8, 1984) 31 figs, 31 refs

KEY WORDS: Ducts, Sound waves, Wave transmission, Impulse testing

An improved impulse technique for acoustic transmission studies in which electroacoustic drivers are used is described. This technique consists of first feeding the convolution of the desired signal and the inverse Fourier transform of the reciprocal of the driver's response to the driver. The driver's response is determined by using an arbitrary input signal and the corresponding output signal. Signal averaging is then used to minimize the background noise. Further refinement of the impulse technique is achieved by incorporating signal editing to remove unwanted portions of a time-domain signal and spectral averaging to improve statistical accuracy of spectral results. A numerical smoothing procedure is developed to eliminate larger fluctuations from spectral distributions. The technique has been validated by comparing experimentally determined acoustic characteristics of duct-nozzle systems with similar results obtained by the impedance tube method.

85-94
Acoustic Radiation from a Semi-Infinite Annular Duct in a Uniform Subsonic Mean Flow
S.W. Rienstra
National Aerospace Lab. NLR, Amsterdam, The Netherlands
J. Sound Vib., 94 (2), pp 267-288 (May 22, 1984) 12 figs, 21 refs

KEY WORDS: Ducts, Sound waves, Wave radiation

An analytical description is derived of the scattered field of a harmonic sound wave coming from an open ended annular duct submerged in a subsonic, coaxial, uniform mean flow. The possibility of vortex shedding from the pipe exit edge is included. Explicit

expressions are given for the acoustic power inside the pipe, in the acoustic far field and, in the presence of vortex shedding, in the hydrodynamic far field, and of the power absorbed by the vortex sheet. The formulae are evaluated numerically with the aid of asymptotic expansions, and a method in which complex contour deformation is used.

85-95
Structural Analysis of an LMFBR Shield Assembly Duct under Thermo-Mechanical and Seismic Loads
S.N. Malik, V.K. Sazawal
Westinghouse Electric Corp., Madison, PA
ASME Paper No. 84-PVP-40

KEY WORDS: Ducts, Nuclear reactor containment, Seismic excitation, Temperature effects

Structural analysis of a LMFBR shield assembly duct under thermo-mechanical and seismic loads is presented. The analysis is performed by computing stresses, strains, and creep-fatigue damage at the above core duct load pad due to applied loads.

BUILDING COMPONENTS

85-96
Estimation of First Excursion Probability for Mechanical Appendage System Subjected to Nonstationary Earthquake Excitation
S. Aoki, K. Suzuki
Tokyo Metropolitan Univ., 2-1-1 Fukazawa Setagaya-ku Tokyo, Japan
Bull. JSME, 27 (228), pp 1299-1305 (June 1984) 12 figs, 20 refs

KEY WORDS: Mechanical components, Damage prediction, Earthquake damage, Seismic response

An estimation technique whereby the first excursion probability of the mechanical appendage system subjected to the nonstationary seismic excitation can be conventionally calculated is proposed. The first excursion probability of the appendage system is estimated by using this method.

85-97
Seismic Response of R/C Frame-Wall Structures
A.E. Aktan, V.V. Bertero
Univ. of California, Berkeley, CA 94720
ASCE J. Struc. Engrg., 110 (8), pp 1803-1821 (Aug 1984) 12 figs, 1 table, 17 refs

KEY WORDS: Walls, Reinforced concrete, Seismic response, Multistory buildings

Results are summarized of analytical and experimental studies conducted on physical and analytical models of a 15-story reinforced concrete frame-coupled wall structure. The primary objectives are to evaluate whether or not: the state-of-the-practice leads to a design that accords with the criteria envisioned by seismic design documents; and the state-of-the-art of analysis of reinforced concrete frame-wall structures provides reliable analytical assessments of the seismic behavior of structures. The results indicate that designs based on the Uniform Building Code provisions may in several important ways be inadequate and analytical techniques currently used to evaluate such designs similarly suffer from shortcomings.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

85-98
Turn-Around Loss for Oceanic Sound on a Bottom Slope
D.E. Weston
Admiralty Underwater Weapons Establishment, Portland, Dorset, UK
J. Sound Vib., 94 (2), pp 199-203 (May 22, 1984) 2 figs, 6 refs

KEY WORDS: Underwater sound, Sound waves, Wave propagation

For oceanic sound reflected from a region of bottom slope the turn-around loss equals the sum of the bottom losses, and can be quite low if the total deflection in horizontal angle is low. Simple formulae are derived, and the effects of the slope being finite are discussed.

85-99
Computer Simulation of Spatial Filtering of Modes by Vertical Array Steering and Double Symmetrical Angles of Sight in Shallow Water Propagation
C. Gazanhes, J.L. Garnier, J.P. Sessarego
Laboratoire de Mecanique et d'Acoustique, CNRS B.P. 71, 31 Chemin Joseph Aiguier, 13277 Marseille Cedex 9, France
J. Sound Vib., 94 (2), pp 205-216 (May 22, 1984) 8 figs, 1 table, 5 refs

KEY WORDS: Underwater sound, Sound waves, Wave propagation

A method is proposed for angular fitting for a selected normal mode by means of a steered array. Examples are given for spatial filtering by a single angle of sight and by association of the symmetrical angle of sight. Calculations were made for the particular case corresponding to previous experiments. Identity between the spatial filtering by amplitude shading with functions of one of the normal modes and by electronic steering with phase-shifters is demonstrated. Possibilities for modal spectroscopy and adaptive filtering are investigated.

85-100
Multiple-Element Threshold Signal Detection of Underwater Acoustic Signals in Nongaussian Interference Environments
D. Middleton
Rept. No. NOSC-CR-231, 171 pp (May 18, 1983) AD-A140 620

KEY WORDS: Underwater sound

A weak-signal M-sensor detection theory is developed. Optimum space-time threshold signal detection algorithms are obtained for specific nongaussian underwater acoustic noise environments and for fully canonical cases of general interference and general signal waveforms. These include algorithms for coherent, incoherent, and composite (coherent + incoherent) reception. It is shown that spatial and temporal processing are interchangeable as long as sampling (of the noise data) is statistically independent, in time and in space.

85-101
Ultrasonic Wave Scattering by a Subsurface Flaw in Joined Fluid-Solid Half Spaces
V.V. Varadan, T.A.K. Pillai, V.K. Varadan
Ohio State Univ., Columbus, OH 43210
J. Appl. Mech., Trans. ASME, 50 (4a), pp 802-806 (Dec 1983) 8 figs, 6 refs

KEY WORDS: Sound waves, Wave scattering, Discontinuity-containing media

The scattering of waves by a flaw (cavity or inclusion) that is embedded in an elastic half space at a finite depth below the interface with a fluid half space is studied using the T-matrix approach. Expressions are derived for the scattered fields generated in the fluid and solid half spaces as well as the asymptotic form of the field in the fluid at a large distance from the interface. Numerical results are presented for spherical voids and steel inclusions imbedded in epoxy as well as oblate spheroidal voids in a metal for various flaw depths, scattering geometries, and frequency of the incident wave. The results obtained by keeping different orders of multiple scattering between the flaw and the interface are critically discussed.

85-102
Coupling of Airborne Sound in a Sandy Soil
H.A.J. Vanhoof, K.W.F.M. Dorrman
Laboratorium Elektronische Ontwikkeligen voor de Krijgsmacht TNO Oegstceest, The Netherlands
Rept. No. LEOK-TR-1983-9, TDCK-78614, 50 pp (Sept 19, 1983) N84-23238

KEY WORDS: Sound waves, Wave propagation

Acoustic impulses were used to study coupling of air-borne sound to unattended seismic sensors. Results show that the predominant portion of air-borne excited acoustic energy moves parallel to the surface from source to sensor with the velocity of sound in air, and is coupled into the ground above the sensor. The energy then propagates vertically to the deeper sensors with a velocity of 235 m/sec. In the lower part of the spectrum the acoustically induced signal interferes with the seismic refracted wave induced at the source location.

85-103
Acoustic Holography: Image Reconstruction. 1975 - May, 1984 (Citations from the International Information Service for the Physics and Engineering Communities Data Base)
NTIS, Springfield, VA
207 pp (June 1984) PB84-867589

KEY WORDS: Acoustic holography, Bibliographies

Citations in this bibliography cover reconstruction of holographic imagery in non-destructive testing, and deformation detecting and measuring procedures. Applications such as underground detection, weld degradation, steel fractures, and living tissue in the field of medicine are included. Among the systems discussed for achievement of super-resolution of image reconstruction are acoustic, sonic, optical, ultrasonic, infrared, microwave, seismic, radio and stereophonic. On-line recording, display, and storage of acoustic holographic imagery are included.

SHOCK EXCITATION

85-104
Seismic Response for Multicomponent Earthquakes
M. Ghafory-Ashtiany, M.P. Singh
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA
Rept. No. VPI-E-84-17, 205 pp (Apr 1984) PB84-193747

KEY WORDS: Ground motion, Earthquakes, Seismic response

Earthquake induced ground motions, in general, have six components: three translational and three rotational. These components are also correlated in general. In this study, the response spectrum methods have been developed to obtain the structural design response for such correlated components. An approach has also been developed to obtain the maximum or the worst-case response which could possibly be induced in the structure when it is oriented in a particular direction. The numerical results demonstrating the application of these approaches are presented for the proportionally as well as the nonproportionally damped structures.

85-105
Acoustic Near-Field Properties Associated with Broadband Shock Noise
J.M. Seiner, J.C. Yu
NASA Langley Res. Ctr., Langley, VA
AIAA J., 22 (9), pp 1207-1215 (Sept 1984) 15 figs, 1 table, 14 refs

KEY WORDS: Shock excitation, Noise generation

Shock noise associated with unheated supersonic jets was investigated using a near-field microphone array and a single-sensor wedge-shaped hot-film probe. Both over- and underexpanded cases were investigated using Mach 1.45 and 1.99 convergent-divergent nozzles. Correlation measurements through each shock cell of a single underexpanded case with the Mach 1.45 nozzle were obtained between the hot-film probe and the microphone array. The results of the hot-film/near-field microphone correlations show general agreement with certain theoretical models as to the location for shock noise production. Evidence is provided for the existence of some large-scale flow structure that collectively interacts and phases the motion of the downstream shocks.

85-106
Pressure Wave Propagation in an Air Water Stratified System
T. Stone, S. Banerjee
Alberta Res. Council, Edmonton, Alberta, Canada
U.S. National Congress of Appl. Mechanics, Proc. of the 9th, Cornell Univ., Ithaca, NY, June 21-25, 1982, ASME, 1982, pp 109-115, 12 figs, 8 refs

KEY WORDS: Shock wave propagation

Pressure wave propagation in a stratified gas-water system is investigated to determine the degree of interaction between the phases. The effects of convective nonlinearity and dispersion in the water phase is also investigated.

85-107
Theoretical-Experimental Comparison of the Buckling Caused by Fluid Structure Interaction During a Seismic Load
P. Aillaud, P. Buland, A. Combescure, J.C. Queval
CEA Centre d'Etudes Nucleaires de Saclay, Gif-sur-Yvette, France
Rept. No. CEA-CONF-6995, CONF-8308-05-68, 19 pp (Aug 1983), Intl. Conf. on Struc. Mechanics in Reactor Tech., Chicago, IL, Aug 22, 1983, DE84750716

KEY WORDS: Structure-fluid interaction, Seismic excitation

The buckling of shells subjected to seismic loading is studied. Theorical and experimental investigations are performed on structures consisting of two shells separated by a thin fluid layer and submitted to a seismic type of load.

85-108
Power/Response Spectrum Transformations in Equipment Qualification
J.F. Unruh, D.D. Kana
SWRI, San Antonio, TX
ASME Paper No. 84-PVP-33

KEY WORDS: Equipment response, Seismic analysis, Earthquakes

A review of the power/response spectrum transformation is given with a discussion of input/output relationships for linear systems required for elevated power spectrum generation. Frequency content of earthquake-like signals is discussed with emphasis on the resolution given.

85-109
Evaluation of the Modified Sachs and Ledsham-Pike Scaling of a Nuclear Air Blast
M.L. Crawford
Air Force Inst. of Tech., Wright-Patterson AFB, OH
Rept. No. DS/PH/83-1, 142 pp (Jan 1983)

KEY WORDS: Nuclear explosions, Air blast

The accuracy of modified Sachs and Ledsham-Pike scaling of peak shock hydrodynamic variables from a nuclear burst in air is evaluated. The modified methods are corrections applied to the similarity transform used to compute shock overpressures and related variables for infinite homogeneous atmospheric ambient conditions. This similarity transform no longer applies when the burst and target are located at different altitudes and the modified corrections are applied to account for these varying ambient conditions.The modified Sachs shock kpositions, dynamic pressu The modified Sachs shock positions, dynamic pressures, and overpressures and the Ledsham-Pike overpressures are compared to a fully two dimensional flux-corrected transport finite difference solution.

VIBRATION EXCITATION

85-110
Discontinuous Transitions in Mechanical Systems (Mechanische Systeme mit unstetigen Übergängen)
F. Pfeiffer
Lehrstuhl B für Mechanik, Technische Universität München, Postfach 202420,

D-8000 München 2, Fed. Rep. Germany
Ing. Arch., 54 (3), pp 232-240 (1984)
5 figs, 10 refs (In German)

KEY WORDS: Impact excitation

Impulsive motion of dynamical systems may be caused by external impulsive forces or by impulsive constraints. The latter is investigated with reference to practical problems. An example of a nonlinear oscillator illustrates the theory.

85-111
Roughness-Induced Dynamic Loading at Dry and Boundary-Lubricated Sliding Contacts
A. Soom, C. Kim
State Univ. of New York, Buffalo, NY 14260
J. Lubric. Tech., Trans. ASME, 105 (4) pp 514-517 (Oct 1983) 7 figs, 5 refs

KEY WORDS: Contact vibration, Friction

Measurements of instantaneous normal and frictional forces are made at smoothly sliding hemispherical steel contacts under nominally dry and boundary-lubricated conditions. Normalized contact force fluctuations generated by surface irregularities are presented. Instantaneous frictional relations are characterized by performing spectral and transfer function computations on the measured signals. The qualitative dynamic frictional behavior is shown to be similar at dry and boundary-lubricated contacts. The magnitude of the dynamic loading is considerably reduced in the presence of lubrication.

85-112
Random Vibration: A Survey of Recent Developments
S.H Crandall, W.Q. Zhu
Massachusetts Inst. of Technology, Cambridge, MA 02139
J. Appl. Mech., Trans. ASME, 50 (4b), pp 953-962 (Dec 1983) 66 refs

KEY WORDS: Random vibration, Reviews

A general overview of problems, methods, and results achieved in random vibration since its inception as a technical discipline nearly 30 years ago is given. Particular emphasis is placed on developments during the past 15 years. Development of improved probabilistic models for sources of random excitation and development of more effective random response prediction procedures for nonlinear systems and systems with parametric excitation are surveyed. Development of improved procedures for estimating reliability of systems undergoing random vibration is also investigated.

85-113
Suppression of Finite-Amplitude Effects in Sloshing Modes in Cylindrical Cavities
H.Y. Si
Naval Postgraduate School, Monterey, CA
38 pp (Dec 1983), AD-A140 652

KEY WORDS: Cylindrical cavities, Sloshing

A perturbation expansion is formulated for the three dimensional, nonlinear, acoustic-wave equation with dissipative term describing the viscous and thermal energy losses encountered in a cylindrical cavity. The theoretical results show that nonlinear effects in sloshing modes are strongly suppressed.

85-114
Wind-Induced Vibrations of a Mass-Spring System
A.H.P. van der Burgh
Onderafdeling der Wiskunde en Informatica, Technische Hogeschool, Delft, Netherlands
Rept. No. R-84-4, 16 pp (1984) PB84-185859

KEY WORDS: Mass-spring systems, Wind-induced excitation

Wind-induced vibrations of a special mass-spring system are studied. A nonlinear theory including a starting and limiting mechanism is introduced for systems with one and two degrees of freedom. In the one degree of freedom approach a generalized Van der Pol

equation plays a part. In the two degree of freedom approach, a quadratic system is used to describe the wind-induced vibrations. The equations of motion are analyzed by means of the averaging method.

85-115
Bellows Flow-Induced Vibrations
P.J. Tygielski, H.M. Smyly, C.R. Gerlach
NASA George C. Marshall Space Flight Ctr., Huntsville, AL
Rept. No. NASA-TM-82556, 229 pp (Oct 1983) N84-22912

KEY WORDS: Bellows, Fluid-induced excitation

The bellows flow excitation mechanism and results of comprehensive test program are summarized. The analytical model for predicting bellows flow induced stress is refined. The model includes the effects of an upstream elbow, arbitrary geometry, and multiple piles. A refined computer code for predicting flow induced stress is described which allows life prediction if a material S-N diagram is available.

85-116
Flow Induced Vibrations
S.S. Chen
Argonne National Lab., Argonne, Il
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 301-312, 1 table, 210 refs

KEY WORDS: Fluid-induced excitation

Many structural and mechanical components are subjected to fluid flow, contain fluid or convey fluid. They are, therefore, susceptible to flow induced vibration and instability. An assessment of the state-of-the art in this field is provided. Characterizations of flow induced vibrations, vibrations in stationary fluid, parallel flow and cross flow, acoustoelastic vibration, and design considerations are discussed.

85-117
Computational Methods for Fluid-Structure Interaction
R.E. Nickell, J.J. Carey
Applied Science and Technology, La-Jolla, CA
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 313-322, 2 figs, 36 refs

KEY WORDS: Structure-fluid interaction

Fluid-structure interaction analysis has evolved from an emphasis on acoustic fluid/linear elastic structure representations to full hydrodynamic/-nonlinear structural models. Other physical disciplines, such as aero-structural dynamics and offshore platform structural design, have also contributed to the current state of the art. The choice of the fluid model is crucial to the selection of coupling methodology. The various algorithms are addressed in terms of the fluid approximation, beginning with the most simple to incompressible and compressible fluids undergoing significant motion. The two most general and promising procedures are discussed in detail.

MECHANICAL PROPERTIES

DAMPING

85-118
An Investigation into the Effect of Side-Plate Clearance in an Uncentralized Squeeze Film Damper.
R.A. Cookson, L.J. Dainton
Cranfield Inst. of Tech., Cranfield, Bedford MK43 OAL, UK
J. Engrg. Power, Trans. ASME, 105 (4), pp 935-940 (Oct 1983), 8 figs, 9 refs

KEY WORDS: Dampers, Squeeze film dampers, Bearings

An experimental investigation has been carried out into the influence of side-plate flow restrictors on the performnce of a squeeze film damper bearing. The experimental rig used was a flexible rotor with a disk positioned midway between two squeeze film damper bearings. One of the squeeze

film dampers was fitted with side plates that could be adjusted and accurately located with respect to the squeeze film damper journal. Influence of the side-plate clearance on the ability of the squeeze film damper to reduce the amplitude of the central disk can be considerable if side-plate clearance is less than radial clearance. As the side-plate clearance reduces towards zero, the effectiveness of the squeeze film damper diminishes until the amplitudes obtained are the same as those measured when the rolling-contact bearing is rigidly supported. An interesting type of precessing elliptical orbit was discovered for conditions where the jump phenomenon was operating.

85-119
Inner Damping Identification by Means of Amplitude Dissipative Characteristic. 1. Theory
F. Pochyly, H. Netuka
SIGMA Res. Inst., Olomouc, Czechoslovakia
Strojnícky Časopis, 35 (3), pp 261-271 (1984)

KEY WORDS: Internal damping

A new method based on the inner damping and limit envelope definitions analysis is introduced for the generalized function identification of the inner damping. Some important properties of this function are demonstrated. The results can be applied to dynamical systems with finite as well as indefinite number of degrees of freedom.

85-120
On Isothermal Squeeze Films
J.J. Blech
Technion - Israel Inst. of Technology, Haifa, Israel
J. Lubric. Tech., Trans. ASME, 105 (4), pp 615-620 (Oct 1983)

KEY WORDS: Squeeze film damping

It is shown that squeeze film damping cutoff frequencies can be computed directly from the lowest eigenvalue of the Helmholtz equation. A kinematic mode is proposed and analyzed for the computation of those frequencies and it is demonstrated that Griffin's calculations may underestimate considerably those frequencies. New results are given for the squeeze film behavior between rectangular plates, annuli which are not necessarily thin and plate sectors.

85-121
On the Theoretical Determination of the Damping Coefficients of the Surrounding Medium by Means of the Aerodynamical Boundry-Layer Theory
S. Katsaitis
Ministerium fur Forschung Technologie, Athen Griechenland
Forsch. Ingenieurwesen, 50 (3), pp 69-80 (1984) 10 figs, 2 tables, 6 refs (In German)

KEY WORDS: Damping properties, Boundary layer damping

For a rigid body vibrating longitudinally or torsionally in a viscous medium, damping coefficients are not constant but variable functions depending upon many parameters. The aerodynamical boundary-layer theory and the mechanical principle of energetical balance are applied to determine unknown functions of the damping coefficients of the surrounding medium.

85-122
A New Dynamic Vibration Absorber for Excited Structures (Ein neuer dynamischer Schwingungsdämpfer für schwingungserregte Strukturen)
H.F. Bauer
Institut für Luft- und Rumfahrttechnik, Hochschule der Bundeswehr, München, Fed. Rep. Germany
Forsch. Ingenieurwesen, 50 (4), pp 105-116 (1984), 10 figs, 18 refs(In German)

KEY WORDS: Vibration damping, Wind-induced excitation, Liquid-fluid interaction

Structural systems are very susceptible to wind-excited oscillations. Systems to dampen the dangerous motion

of the structure have not been very effective. A new damping device is suggested consisting of a completely filled liquid container filled with two immiscible liquids. The motion of the interface is able to effectively dampen the structure. The effectiveness is exhibited for the coupled structure-liquid system and shows good results in preventing structural motion.

FATIGUE

85-123
Metal Fatigue Testing: Techniques and Equipment. 1966 - June, 1984 (Citations from the Metals Abstracts Data Base)
NTIS, Springfield, VA
148 pp (June 1984) PB84-867829

KEY WORDS: Fatigue tests, Metals, Bibliographies

This bibliography contains 305 citations concerning specialized equipment for the testing of metal fatigue under a variety of conditions. Apparatuses are described for cyclic testing fatigue due to bending, torsional stress, corrosion, material dislocations, thermal effects, etc.

85-124
Fatigue-Multiaxial Aspects
E.H. Jordan
Univ. of Connecticut, Storrs, CT
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 507-518, 5 figs, 77 refs

KEY WORDS: Fatigue tests, Testing techniques

An appropriate theory of multiaxial fatigue can only be selected on the basis of the results of experiments. There are numerous examples where experimenters testing similar metals have come to different conclusions regarding the validity of various theories. These discrepancies are put into perspective to provide some basic information for planning experimental programs. Some of the difficulties and complexities encountered in multiaxial fatigue experiments are discussed and recent work on theories of multiaxial fatigue are reviewed.

85-125
Simulated Flight Fatigue of an Alpha/-Beta Titanium Alloy
C.M. Ward-Close
Royal Aircraft Establishment, Farnborough, Hants GU14 6TD, UK, Intl. J. Fatigue, 6 (3), pp 139-149 (July 1984) 13 figs, 4 tables, 13 refs
Intl. J. Fatigue, 6 (3), pp 139-146 (July 1984) 13 figs, 4 tables, 13 refs

KEY WORDS: Fatigue tests, Flight simulation

Simulated flight (FALSTAFF) fatigue tests have been carried out on precracked single edge-notch test-pieces of IMI 550 titanium alloy. Predictions of simulated flight fatigue behavior have been made from constant amplitude fatigue data using a damage accumulation approach with no allowance for load history. The predicted lives were conservative compared with measured lives, and accurate within a factor of approximately two. Retardation of fatigue crack growth increased with increasing load amplitude.

85-126
Cycle Counting for Fatigue Crack Growth Analysis
R. Sunder, S.A. Seetharam, T.A. Bhaskaran
National Aeronautical Lab., Bangalore - 560017, India
Intl. J. Fatigue, 6 (3), pp 147-156 (July 1984) 18 figs, 1 table, 20 refs

KEY WORDS: Fatigue tests, Crack propagation

Fatigue crack propagation tests were carried out on an Al-Cu alloy under specially designed complex load sequences. Electron fractography of the fatigue fracture surfaces suggests that rainflow cycle counting is appli-

cable to the analysis of fatigue crack growth under complex load sequences.

85-127
Morphometrical Evaluation of Surface Roughness During the Initial Fatigue Stage in an Austenitic Steel
J. Woodtli-Folprecht
Swiss Federal Labs. for Materials Testing and Res. (EMPA), Überlandstrasse 129, CH-8600 Dubendorf, Switzerland
Intl. J. Fatigue 6 (3), pp 157-167 (July 1984) 14 figs, 2 tables, 9 refs

KEY WORDS: Surface roughness, Fatigue life, Steel

The microscopic behavior of surface deformation in the precracked fatigue stage of AISI 310 stainless steel was examined. The fatigue experiments were conducted in a special servohydraulic miniature testing machine inside a scanning electron microscope. The object of the study was the quantitative determination of material damage caused by fatigue straining. The roughness values were determined by using both a stereo-photogrammetrical method and a contact stylus instrument. Both morphometrical methods allowed the deformation of fatigued surfaces to be quantified.

85-128
Comparison of Theoretical Estimates and Experimental Measurements of Fatigue Crack Growth under Severe Thermal Shock Conditions: Part 1 --Experimental Observations
D. Marsh, D. Green, R. Parker
Springfields Nuclear Labs., Preston, UK
ASME Paper No. 84-PVP-34

KEY WORDS: Fatigue life, Crack propagation

Results are reported of an experiment where a severe thermal cycle, comprised of alternate upshocks and downshocks, is applied to an axisymmetric feature with an internal, partial penetration weld and crevice.

85-129
Fatigue Life Estimates for a Notched Member in a Corrosive Environment
P. Kurath, Z. Khan, D.F. Socie
Univ. of Illinois at Urbana-Champaign
ASME Paper No. 84-PVP-4

KEY WORDS: Fatigue life, Corrosion fatigue

Reliable constant amplitude corrosion fatigue life estimates for notched, aluminum 5454-H32 alloy specimens were obtained from smooth and crack growth specimens tested in a corrosive environment at the frequency of interest. Estimates were obtained without detailed consideration of the growth of small cracks in the notch region or the electrochemical issues involved with the crack nucleation mechanism.

85-130
Plastic Work Interaction Damage Rule Applied to Narrow-Band Gaussian Random Stress Situations
R.G. Lambert
General Electric Co., Utica, NY
ASME Paper No. 84-PVP-3

KEY WORDS: Fatigue life

This paper extends the application of the plastic work interaction damage rule to narrow-band Gaussian random stress situations. The derived stress-life mathematical expression is of a power law form. The predicted fatigue life is more conservative than that predicted using a conventional linear damage rule.

85-131
Structural Fatigue Reliability Considerations in Series Systems
L. Kjerengstroen, P.H. Wirsching
Det norske Veritas, Oslo, Norway
ASME Paper No. 84-PVP-2

KEY WORDS: Fatigue life, Reliability

Reliability analyses of series systems of mechanical or structural components with emphasis of fatigue, are described. The goal was to relate component to system reliability. A comparison study of probability

distributions of cycles to failure for several sets of fatigue data is also included.

85-132
A Review of the B-Model Approach to Cumulative Damage Processes
F. Kozin, J.L. Bogdanoff
Polytechnic Inst. of New York, Farmingdale, NY
ASME Paper No. 84-PVP-1

KEY WORDS: Fatigue life, Wear

Described is a recent phenomenological approach to cumulative damage that has allowed a comprehensive study of the probabilistic evolution of fatigue failure, fatigue crack growth, and wear.

85-133
Effect of Cutting Speed and Tool Rake Angle on the Fatigue Life of 2024-T351 Aluminium Alloy
S. Jeelani, M. Musial
School of Engrg. and Architecture, Tuskegee Inst., Tuskegee, AL 36088
Intl. J. Fatigue, 6 (3), pp 169-172 (July 1984) 6 figs, 17 refs

KEY WORDS: Fatigue life, Machining

Ring-shaped specimens of 2024-T351 aluminium alloy were machined orthogonally on a lathe equipped with a quick-stop device at cutting speeds of 0.5 - 1.5 ms^{-1} with tools having positive rake angles in the range 10-30°. The machined specimens were then fatigued at a selected stress and the resulting fatigue lives were compared with that of the virgin material. The surfaces of the specimens were examined using optical and scanning electron microscopy.

85-134
Cycle Stress-Strain Behavior
R.W. Landgraf
Ford Motor Co., Dearborn, MI
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 481-485, 12 figs, 19 refs

KEY WORDS: Fatigue life

Patterns of cyclic response and the parameters used to describe them are reviewed. The influence of material type and processing is shown, followed by a discussion of applications of such information in fatigue analysis. An attempt is made to assess current capabilities and to highlight areas requiring additional investigation.

85-135
Fatigue Life Prediction for Complex Load Versus Time Histories
N.E. Dowling
Westinghouse R&D Ctr., Pittsburgh, PA
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 487-498, 15 figs, 53 refs

KEY WORDS: Fatigue life, Prediction techniques

Fatigue life prediction for complex load vs time histories is considered from the viewpoint of separating the history into discrete events to be used with constant amplitude fatigue data in a cumulative damage type of analysis. Highly irregular histories require special attention, with minor load excursions being considered in cycle counting as temporary interruptions of larger load cycles. Local notch plasticity and mean stress effects are interrelated. Such effects are most rationally accounted for in terms of local notch stresses and strains. A life prediction procedure for notched members, based on modeling of the stresses and strains occurring locally at the notch, is described.

85-136
High Cycle Fatigue
P. Soo
Brookhaven National Lab., Upton, NY
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich,

eds., ASME-PVD, 1982, pp 499-506, 3 figs, 1 table, 88 refs

KEY WORDS: Fatigue life

Developments in high cycle fatigue technology over the last decade are summarized. Uses of such data in the engineering field and types of research which have been carried out to develop a better understanding of high cycle fatigue failure mechanisms are outlined. In addition, the relationships between low-cycle, high-cycle, and ultra high-cycle fatigue are discussed.

85-137
Fatigue Mechanisms
S.D. Antolovich
Univ. of Cincinnati, Cincinnati, OH
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 533-540, 13 figs, 14 refs

KEY WORDS: Fatigue life

Some of the basic aspects of the relationship between fatigue behavior, deformation mode and damage accumulation are discussed.

85-138
Static and Fatigue Failure Criteria for Unidirectional Fiber Composites
Z. Hashin
Tel-Aviv Univ., Tel-Aviv, Israel
U.S. National Congress of Appl. Mechanics, Proc. of the 9th, Cornell Univ., Ithaca, NY, June 21-25, 1982, ASME, 1982, pp 213-218, 7 figs, 13 refs

KEY WORDS: Fatigue life, Fiber composites

Recent work on establishment of three dimensional macroscopic static and fatigue failure criteria for unidirectional fiber composites is reviewed. The basis of the methods presented is recognition of the various distinct failure modes of such composites, the transverse isotropy of the material and modeling by quadratic stress polynomials. In the static case there are four distinct failure modes leading to a piecewise smooth criterion consisting of four smooth branches. In the case of fatigue failure there is a family of failure criteria, each associated with a different lifetime. Each member of the family consists of two smooth parts. Particularly simple results are obtained for reversed cycling. Static and fatigue failure predictions are compared with test data off-axis specimens.

85-139
Prediction of Fatigue Crack-Growth Patterns and Lives in Three-Dimensional Cracked Bodies
J.C. Newman, Jr., I.S. Raju
NASA Langley Res. Ctr., Hampton, VA
Rept. No. NASA-TM-85787, 14 pp (Apr 1984) N84-22979

KEY WORDS: Fatigue life, Crack propagation

Fatigue crack growth patterns and lives for surface cracks, surface cracks at holes, and corner cracks at holes in three dimensional bodies were predicted. Linear-elastic fracture mechanics concepts, modified to account for crack-closure behavior, were used. Predictions were made using stress intensity factor equations for these crack configurations and the fatigue crack-growth relationship for the material of interest. The crack configurations were subjected to constant-amplitude fatigue loading under either remote tension or bending loads. The predicted crack growth patterns and crack growth lives for aluminum alloys agreed well with test data from the literature.

85-140
Review of the Effects of Microstructure on Fatigue in Aluminum Alloys
J. Telesman
NASA Goddard Space Flight Ctr., Greenbelt, MD
Rept. No. E-2061, NASA-TM-83626, 36 pp (Apr 1984) N84-22735

KEY WORDS: Fatigue life, Crack propagation, Aluminum, Reviews

Literature survey was conducted to determine effects of different microstructural features and different load histories on fatigue crack initiation and propagation of aluminum alloys. Comparison of microstructure and monotonic and cyclic properties between powder metallurgy (P/M) and ingot metallurgy (I/M) alloys is presented. The two alloys that are representative of each process on which the comparison is focused are X7091 and 7050. Included is a detailed description of the microstructure produced through the P/M and I/M processes. The effect of each pertinent microstructural feature on monotonic and cyclic properties is discussed. Also discussed are the proposed mechanisms for crack initiation and propagation, as well as effects of aggressive environments on these cyclic properties.

85-141
An Analysis of the Fatigue/Creep Behavior of 304 Stainless Steel Using a Continuous Damage Approach
R. Gomuc, T. Bui-Quoc
Ecole Polytechnic, Montreal, Canada
ASME Paper No. 84-PVP-38

KEY WORDS: Fatigue life, Steel

The correlation between predictions and available experimental results obtained on Type 304 SS from 538 to 650°C under various loading conditions is discussed. The predictive technique is based on the separate functions for fatigue and for creep. The effect of the tension hold time in interspersed creep fatigue loading on the material life is investigated.

85-142
Rheological Model for Cyclic Loading of Concrete
A. Fafitis, S.P. Shah
Northwestern Univ., Evanston, IL 60201
ASCE J. Struc. Engrg., 110 (9), pp 2085-2102 (Sept 1984) 13 figs, 22 refs

KEY WORDS: Concrete, Cyclic loading, Rheological properties

A rheological stochastic model to predict the cyclic stress-strain behavior of concrete subjected to uniaxial compressive loading is proposed. The model consists of rheological elements with random state variables with exponential distributions. The model has 3 parameters and can be calibrated by experimental data from only the monotonically increasing loading. It simulates well the main known characteristics of concrete response to cyclic loading, such as strain softening, path dependency, stiffness degradation, and the concept of envelope curve. The formulation is of the total strain type and all formulas are derived in closed form.

85-143
Multitechnique Studies on Fretting Fatigue; Influence of Surface Treatment
H. Sander
Bundesanstalt fuer Materialpruefung, Berlin, Fed. Rep. Germany
13 pp (Jan 1984) AD-A140 812

KEY WORDS: Fretting fatigue, Steel

The problem of fretting fatigue is becoming more acute as increasing demands are placed on materials. A project has been initiated to investigate the influence of mechanical surface treatments on the fretting fatigue behavior of steel specimens. One of the initial steps taken has been the development of an experimental apparatus and a test technique that allows the fretting and fatigue process to occur simultaneously. The experimental program and the apparatus needed for investigating the effect of mechanical surface treatments on fretting fatigue is described.

WAVE PROPAGATION

85-144
Elastic Waves in Solids
Yih-Hsing Pao
Cornell Univ., Ithaca, NY 14853

J. Appl. Mech., Trans. ASME, 50 (4b), pp 1152-1164 (Dec 1983) 161 refs

KEY WORDS: Elastic waves, Reviews

Research contributions over the past 50 years on the theory and analysis of elastodynamics are reviewed. Topics reviewed are general theories, steady-state waves in waveguides, transient waves in layered media, diffraction and scattering, and one and two-dimensional theories of elastic bodies. A brief discussion on the direct and inverse problems of elastic waves completes this review.

85-145
Electro-Magneto-Thermo-Elastic Plane Waves in Rotating Media with Thermal Relaxation
S.K. Roy Choudhuri
Burdwan Univ., Burdwan, W. Bengal, India
Intl. J. Engrg. Sci., 22 (5), pp 519-530 (1984) 10 refs

KEY WORDS: Elastic waves, Wave propagation

A study is made of the propagation of plane electro-magneto-thermo-elastic harmonic waves in an unbounded isotropic conducting medium permeated by a primary uniform magnetic field. The entire medium rotates with a uniform angular velocity. The thermal relaxation time of heat conduction, electric displacement current, coupling between heat flow density and current density and between temperature gradient and electric current are analyzed. A more general dispersion relation is obtained to determine the effects of rotation, relaxation time and the external magnetic field on the phase velocity of the waves. Perturbation techniques are used to study the influence of small magneto-elastic and thermo-elastic couplings on the phase velocity of the waves. Cases of low and high frequencies are also studied to determine the effect of rotation, thermoelastic and magneto-elastic couplings on the waves.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

85-146
Impact Force Prediction Using Measured Frequency Response Functions
R.J. Thornhill, C.C. Smith
International Business Machines Corp., 11400 Burnet Rd., Austin, TX 78758
J. Dynam. Syst., Meas. Control, Trans. ASME, 105 (4), pp 227-231 (Dec 1983) 10 figs, 5 refs

KEY WORDS: Impact force, Prediction techniques, Frequency response function

A method is presented for predicting impact forces using measured frequency response functions when an ideal mass elastically impacts a stationary structure. It is shown that a frequency response function measured at the point of impact on the structure together with the impactor's mass and velocity can be used to form a function which, after inverse Fourier transformation, yields predicted force. After the basic equation is developed, predicted and measured force pulses are compared for a steel missile impacting an aluminum casting. The limitations of the method due to hardware and experimental technique are also discussed.

85-147
Determination of Critical Parameters in Large Flexible Space Structures with Uncertain Modal Data
R.K. Yedavalli, R.E. Skelton
Stevens Inst. of Tech., Hoboken, NJ 07030
J. Dynam. Syst., Meas. Control, Trans. ASME, 105 (4), pp 238-244 (Dec 1983) 1 fig, 1 table, 14 refs

KEY WORDS: Modal analysis, Spacecraft, Control equipment

The problem of control design for large flexible space structures with uncertain modal data is addressed. The concepts of modal cost analiysis are applied to flexible space structures with these uncertain parameters: modal damping, modal frequencies, and mode shapes at actuator (sensor) locations. A quadratic function of displacements and displacement rates is used as a performance metric. In this case it is possible to obtain explicit formulas for the cost contributions labeled "modal costs" and "parameter costs." This type of cost decomposition analysis by which one can determine the significant modes and parameters can be useful in model reduction, parameter estimation, and structure redesign.

85-148
Modal Analysis of Machine Tool Structures Based on Experimental Data
K.F. Eman, K.J. Kim
Univ. of Wisconsin-Madison, Madison, WI 53706
J. Engrg. Indus., Trans. ASME, 105 (4), pp 282-287 (Nov 1983) 7 figs, 3 tables, 12 refs

KEY WORDS: Modal analysis, Autoregressive moving average models, Machine tools

The basic problem in modal analysis of machine tool structures is the extraction of modal parameters from the measured transfer function data. Conventionally this task is performed in two steps. The transfer function is determined using a Digital Fourier Analyzer followed by a suitable curve fitting procedure. In order to avoid the inherent problems associated with these procedures a new approach for modal analysis is proposed. Anticipating the stochastic nature of the systems excitation and response Modified Autoregressive Moving Average Vector models (MARMAV) are proposed. The modeling procedure yields a parametric representation of the structural behavior allowing the extraction of the modal information in one step, directly, rather than in two. The mathematical foundation for the approach is given along with its application to a simulated three-degree-of-freedom system and a knee type milling machine.

85-149
Pseudo-Dynamic Qualification of Seismic Category 1: Valve Assemblies
P. Avitabile, H. Sonderegger
ITT Grinnell Corp., Providence, RI
ASME Paper No. 84-PVP-15

KEY WORDS: Modal analysis, Valves, Seismic analysis

Techniques are presented for determining estimates of mass and stiffness of a valve assembly from experimental modal data. This is for use in a piping dynamic model for seismic applications when the valve assembly natural frequency is less than 33 Hz and the valve/piping dynamic coupling must be considered.

85-150
Time Aliasing: A Digital Data Processing Phenomenon
R.J. Thornhill, C.C. Smith
International Business Machines Corp., Austin, TX 78758
J. Dynam. Syst., Meas. Control, Trans. ASME, 105 (4), pp 232-237 (Dec 1983) 13 figs, 1 table, 3 refs

KEY WORDS: Signal processing techniques

The frequency sampling theorem is developed and interpreted for a function of frequency which was sampled either directly or indirectly by spectral identification techniques. An example of the results of time aliasing when the frequency resolution is too coarse is presented. A generalized window is developed which implements a zoom inverse discrete Fourier transform for avoiding undesirable time aliasing effects.

85-151
Synthesis of Arbitrary Broadband Signals for a Parametric Array
S. Singhai, J.G. Zornig
Dept. of Navy, Washington, DC
24 pp (July 1983) U.S. Patent Appl. No. 6-516-13

KEY WORDS: Signal processing techniques

A method for synthesizing arbitrary broadband signals for a parametric array is presented. The method computes the input waveform needed to a parametric array source to obtain a received signal of a prescribed waveform. Fourier transform and inverse transform of digitized received signals are used to make computations in either the frequency or time domain. The method uses an iterative process to obtain the received signal very close to the received signal of the desired waveform.

85-152
Vibration Analysis by Multiple Components Mode Synthesis Method
M. Ookuma, A. Nagamatsu
Tokyo Inst. of Tech., 12-1, Ohokayama 2-chome, Meguro-ku, Tokyo, Japan
Bull. JSME, 27 (228), pp 1288-1293 (June 1984) 6 figs, 2 refs

KEY WORDS: Component mode synthesis, Vibration analysis

A multiple component mode synthesis method is proposed for analyzing the vibration of complex mechanical structures. By this method a structure can be analyzed with a computer with smaller memory capacity than either the ordinary component mode synthesis method or the finite element method. As a numerical example a plate is analyzed by the present method and the results are compared with those by experiment and the finite element method.

85-153
Comparison of Component Mode Synthesis Method with MSC-NASTRAN
M. Ookuma, A. Nagamatsu
Tokyo Inst. of Tech., 12-1, Ohokayama 2-chome, Meguro-ku, Tokyo, Japan
Bull. JSME, 27 (228), pp 1294-1298 (June 1984) 12 figs, 7 tables, 2 refs

KEY WORDS: Natural frequencies, Component mode synthesis, Finite element technique, NASTRAN

A component mode synthesis method (CMS) and a multiple component mode synthesis method (MCMS) were proposed in previous papers for analyzing the vibration of complex mechanical structures. In this report, CPU time and accuracy of calculation by CMS and MCMS are compared with those with MSC-NASTRAN concerning the natural frequencies and the dynamic responses of two model structures. It is shown that the vibration of these structures can be analyzed by both CMS and MCMS with much less CPU time and with the same accuracy than by MSC-NASTRAN.

85-154
Incremental Harmonic Balance Method with Multiple Time Scales for Aperiodic Vibration of Nonlinear Systems
S.L. Lau, Y.K. Cheung, S.Y. Wu
Hong Kong Polytechnic, Hong Kong
J. Appl. Mech., Trans. ASME, 50 (4a), pp 871-876 (Dec 1983) 4 figs, 2 tables, 9 refs

KEY WORDS: Harmonic balance method, Random vibration

An incremental harmonic balance method with multiple time scales is presented. As a general and systematic computer method, it is capable of treating aperiodic "steady-state" vibrations such as combination resonance, etc. This method is not subjected to the limitation of weak nonlinearity. To show the essential features of the new approach, the almost periodic free vibration of a clamped-hinged beam is computed.

85-155
Characteristics of Microphone Arrangements for Sound Intensity Measurement
P.S. Watkinson, F.J. Fahy
Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton S09 5NH, UK
J. Sound Vib., 94 (2), pp 299-306 (May 22, 1984) 7 figs, 12 refs

KEY WORDS: Sound intensity, Measurement techniques, Two microphone technique

Experimentally determined frequency and directional pressure responses are presented for a face-to-face microphone configuration. The implications of these results for the use of such a

configuration for two-microphone sound intensity measurement are discussed.

85-156
Multiple-Spark Camera for Dynamic Photoelastic and Caustic Studies
A. Shukla, H. Nigam
Univ. of Rhode Island, Kingston, RI
Exptl. Tech., 8 (8), pp 17-19 (Aug 1984) 4 figs, 6 refs

KEY WORDS: Photoelastic analysis, Optical methods, Measuring instruments, Fracture properties

Dynamic photoelasticity and the method of caustics (also known as the shadow-spot method) are the two most popular optical techniques used today to study dynamic fracture. A new multiple-spark camera is described with a dual-fiber optic system which can generate photoelastic as well as caustic data.

85-157
Effect of Tubing on Measurements of Small Transient Pressure Signals in Liquids
M.M. Farid
Univ. of Basrah, Basrah, Iraq
J. Dynam. Syst., Meas. Control, Trans. ASME, 105 (4), pp 262-264 (Dec 1983) 3 figs, 2 tables, 11 refs

KEY WORDS: Pressure gages, Tubing, Instrumentation, Transient response

It is often necessary to connect the pressure transducer used for measurements of static and dynamic pressure signals to the pressure source by means of a connecting tube. The effects of the tube length and diameter on a relatively small step pressure signal in a liquid system have been studied experimentally and analyzed theoretically. Theoretical equations to predict the natural frequency and damping coefficient of the system are obtained so that proper length and diameter of tubing can be selected for minimum distortion of the step input signal. Agreement between theoretical predictions and experimental measurements was found to be reasonably good.

85-158
Etched Silicon Vibrating Sensor
J.C. Greenwood
Standard Telecommunication Labs., Ltd., London Rd., Harlow, Essex CM17 9NA, UK
J. Phys., E: Sci. Instrum., 17 (8), pp 650-652 (Aug 1984) 6 figs, 4 refs

KEY WORDS: Instrumentation, Detectors, Resonators

The development of a frequency output absolute pressure sensor is described. The sensor element is etched out of single crystal silicon using boron doping to define the shape of the mechanical resonators on one side of a wafer and the diaphragm on the other.

85-159
Experimental Methods in Applied Mechanics
I.M. Daniel
Illinois Inst. of Tech., Chicago, IL 60616
J. Appl. Mech., Trans. ASME, 50 (4b), pp 963-976 (Dec 1983) 26 figs, 46 refs

KEY WORDS: Testing techniques, Reviews

An overview is presented of recent developments and the current status of several experimental mechanics methods; i.e., strain gages, moiré, photoelasticity, and interferometry. Examples of applications of these methods are given. Progress has been noted in all aspects, including methodology, data acquisition instrumentation, data processing, and range of applications. The trend is to tackle more difficult problems and to take full advantage of technological advances.

85-160
Microbarograph Measurements Around the Large French Blast Simulator
J.W. Reed
Sandia National Labs., Albuquerque, NM

Rept. No. SAND-84-112, 58 pp (Jan 1984)
DE84007820

KEY WORDS: Shock tubes, Test facilities

Airblast propagations from large shock tubes may cause acoustic insults or possible cosmetic damage to the surrounding environment. Plans for constructing a large shock tube facility and the associated environmental impact assessment necessitated a measurement program to verify and refine prediction models based on small shock tubes and various guns. Microbarograph measurements were made at eight locations around a large French blast simulator on five tests. Results were analyzed to yield some modest adjustments to an available British shock tube prediction system.

DIAGNOSTICS

85-161
Electric-Generator Pulsations Can Cause Turbine-Blade Failure
F.H. Wolff, A.J. Molnar
Engineering Analytical Dynamics Corp.
Power, 128 (8), pp 107-108 (Aug 1984) 7 figs

KEY WORDS: Diagnostic techniques, Blades, Turbine blades, Crack detection

In large generators unavoidable small electrical-phase unbalances produce significant second-harmonic generator air-gap torque oscillations at 120 Hz in a 60-Hz electrical system. This causes the fracture of turbine blades. Procedures for identifying and solving the problem are suggested.

85-162
Analysis of Project Management Support to Develop a Reactor Coolant Pump Monitoring and Diagnostic System
C.E. McLain, G.A. Sommerfield
Toledo Edison Co., Toledo, OH
ASME Paper No. 84-PVP-47

KEY WORDS: Diagnostic instrumentation, Monitoring techniques, Pumps, Nuclear reactors

This paper reports on the management of the project, documents project performance, and provides analyses of the strengths and weaknesses observed. Also provided are a variety of exhibits to document schedule and cost performance by the owner and his subcontractors.

85-163
Quantitative Ultrasonic Nondestructive Evaluation Methods
R.B. Thompson
Iowa State Univ., Ames, IA 50011
J. Appl. Mech., Trans. ASME, 50 (4b), pp 1191-1201 (Dec 1983) 12 figs, 151 refs

KEY WORDS: Diagnostic techniques, Testing techniques, Nondestructive testing, Ultrasonic techniques

Quantitative ultrasonic techniques for determining the serviceability of structural components are reviewed. Particular emphasis is placed on the use of forward and inverse elastic wave scattering theory as a fundamental foundation for predicting the probability of flaw detection. Ultrasonic measurement techniques for the determination of distributed failure-related properties such as residual stresses are discussed. The status of the prediction of failure by the detection of acoustic emission precursors is reviewed.

85-164
Thermodynamic Models for Pipeline Gas Turbine Diagnostics
H.I.H. Saravanamuttoo, B.D. MacIsaac
Carleton Univ., Ottawa, Canada
J. Engrg. Power, Trans. ASME, 105 (4), pp 875-884 (Oct 1983) 17 figs, 13 refs

KEY WORDS: Diagnostic techniques, Turbines, Gas turbines, Pipelines,

Thermodynamic models suitable for use as diagnostic tools for pipeline gas turbines have been developed. A basic requirement was the prediction of the

performance of gas turbines subject to in-service deterioration, including effects such as compressor fouling, foreign object damage, and turbine damage. Thermodynamic models capable of operation over the complete running range expected were created with a provision for introducing arbitrarily controlled degradations. Models for a variety of types of gas turbines currently in pipeline use have been tested, demonstrating good agreement with user experience. The models are extremely flexible in use and may be used either for investigation of specific problems or to increase user understanding of operating problems.

BALANCING

85-165
Design Characteristics of a Hard Mount Balancing Machine
D.A. Donovan, N.L. Field, B.B. Seth
Ford Motor Co., Redford, MI
ASME Paper No. 84-DE-5

KEY WORDS: Balancing machines

The design features of a hard mount balancing machine for balancing of engines in a production environment are described. The stringent balancing accuracy requirements for the product were met through an integrated approach utilizing computer aided design of the stand. Compared with conventional engine balancers where the engine is self powered, this test stand uses an external drive to motor the engine.

MONITORING

85-166
Loose-Part Monitoring Programs and Recent Operational Experience in Selected U.S. and Western European Commercial Nuclear Power Station
R.C. Kryter
Oak Ridge National Lab., TN
Rept. No. ORNL/TM-9107, 58 pp (Apr 1984) NUREG/CR-3687

KEY WORDS: Nuclear power plants, Monitoring techniques, Acoustic techniques

Technical personnel at thirteen nuclear power stations were interviewed to ascertain their collective experience with acoustic-based loose-part monitoring systems (LPMSs). Special attention was given to the number and location of accelerometers required to reliably detect and locate loose parts in both pressurized- and boiling-water reactor types. Detection sensitivity to loose objects in both primary and secondary coolant loops, false alarm experience, calibration procedures, day-to-day monitoring system operation, etc., were also investigated. The individual utilities' responses to questions addressing these issues are provided, along with the author's summary and interpretation of what the information gathered means in a collective sense.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

85-167
On the 1/2-th Subharmonic Vibrations of a Non-linear Vibrating System with a Hard Duffing Type Restoring Characteristic
Y. Tsuda, J. Inoue, H. Tamura, A. Sueoka
Ohita Univ., Dannoharu 700, Ohita-shi, Japan
Bull. JSME, 27 (228), pp 1280-1287 (June 1984) 8 figs, 11 refs

KEY WORDS: Subharmonic oscillation, Unbalanced mass response, Gravity effects

Assuming that both a periodic exciting force and a constant force are acting on a nonlinear vibrating system, the 1/2-th subharmonic vibrations of a system with a hard, Duffing type characteristic are investigated. It is

shown that the 1/2th subharamonic oscillations can occur in the same system, even if only a periodic force is the driving force. Analytical results are compared with the results obtained by numerical integration from the same system carried out by the Runge-Kutta-Gill method. It appears that the present theory gives relatively satisfactory results in calculating these vibrations.

85-168
An Alternative Analysis of the Plane Stick-Slip Problem
A. Dutta
National Chemical Lab., Pune-411008, India
J. Appl. Mech., Trans. ASME, 50 (4a), pp 863-868 (Dec 1983)

KEY WORDS: Stick-slip response

The plane stick-slip problem has been solved analytically using the separation of variable technique. The essence of the mathematical procedure is to solve the problem separately for the stick and slip regions and then to match the two solutions at the exit plane. The present solution, which is relatively easy to evaluate, yields results that compare favorably with those obtained by the Wiener-Hopf technique. Furthermore, the stick-slip solution has been used to estimate the expansion of a two-dimensional plane Newtonian jet at very low Reynolds numbers. For capillary numbers less than 0.1, the approximate method predicts swell ratios that are in fairly good agreement with those obtained from a more elaborate numerical solution of the jet swell problem.

85-169
Strange Attractors and Chaos in Nonlinear Mechanics
P.J. Holmes, F.C. Moon
Cornell Univ., Ithaca, NY 14853
J. Appl. Mech., Trans. ASME, 50 (4b), pp 1021-1032 (Dec 1983) 20 figs, 61 refs

KEY WORDS: Mapping

Several examples of nonlinear mechanical and electrical systems and related mathematical models that display chaotic dynamics or strange attractors are reviewed. Some simple mathematical models -- iterated piecewise linear mappings -- are introduced to explain and illustrate the concepts of sensitive dependence on initial conditions and chaos. The role of homoclinic orbits and the horseshoe map in the generation of chaos is described. How existence of such features can be detected in specific nonlinear differential equations is indicated.

85-170
Index Evaluation for Dynamical Systems and its Application to Locating all the Zeros of a Vector Function
C.S. Hsu, R.S. Guttalu
Univ. of California, Berkeley, CA 94720
J. Appl. Mech., Trans. ASME, 50 (4a), pp 858-862 (Dec 1983), 3 figs, 2 tables, 19 refs

KEY WORDS: Point mapping method

An index evaluation method is discussed. It can also serve as the basis of a procedure to locate all the zeros of a vector function. An application of the procedure is made to a strongly nonlinear point-mapping dynamical system in order to locate all the periodic solutions of period one and period two, 41 in total number.

85-171
A Periodically Forced Impact Oscillator with Large Dissipation
S.H. Shaw, P.J. Holmes
Cornell Univ., Ithaca, NY 14853
J. Appl. Mech., Trans. ASME, 50 (4a), pp 849-857 (Dec 1983)

KEY WORDS: Oscillators, Periodic excitation, Harmonic excitation

The simple harmonic oscillator with harmonic excitation and a constraint that restricts motions to one side of the equilibrium position is considered. On the achievement of a specified displacement, the direction of motion is reversed using the simple impact rule. The coefficient of restitution for this impact, r, is taken

to be small. For r=0 the motions of the system can be studied using a one-dimensional mapping. Analysis shows that stable periodic orbits exist at almost all forcing frequencies but that transient nonperiodic or chaotic motions can also occur. Moreover, over certain (narrow) frequency windows arbitrarily long stable periodic motions exist.

85-172
The Lumped Parameter Method for Elastic Impact Problems
Y. Lee, J.F. Hamilton, J.W. Sullivan
The Pennsylvania State Univ., State College, PA 16801
J. Appl. Mech., Trans. ASME, 50 (4a), pp 823-827 (Dec 1983), 8 figs, 13 refs

KEY WORDS: Lumped parameter method, Impact excitation

Transverse impact problems have recently been solved by several different methods including Timoshenko's integral equation method, the energy method, and finite element method. This paper presents a lumped parameter method for impact analysis, which is attractive for the solutions of impact of complex bodies. The advantages are in its simplification of mathematical formulation, computational efficiency, and improved understanding of the coupling effect of excited modes on the occurrence of multiple impacts. Experimentally obtained information of the dynamic characteristics of these impacting bodies permit easy extension to nonsimple body shapes.

85-173
Finite Element Analysis of Dynamic Coupled Thermoelasticity Problems with Relaxation Times
J.H Prevost, D. Tao
Princeton Univ., Princeton, NJ 08544
J. Appl. Mech., Trans. ASME, 50 (4a), pp 817-822 (Dec 1983), 4 figs, 1 table, 25 refs

KEY WORDS: Transient response, Finite element technique, Thermoelasticity

A general finite element model is proposed to analyze transient phenomena in thermoelastic solids. Green and Lindsay's dynamic thermoelasticity model is selected for that purpose since it allows for second sound effects and reduces to the classical model by appropriate choice of the parameters. Time integration of the semidiscrete finite element equations is achieved by using an implicit-explicit scheme proposed by Hughes, et al. The procedure proves to be most effective and versatile in thermal and stress wave propagation analysis. A number of examples are presented which demonstrate the accuracy and versatility of the proposed model and the importance of finite thermal propagation speed effects.

85-174
Dynamic Plasticity
R.J. Clifton
Brown Univ., Providence, RI 02912
J. Appl. Mech., Trans. ASME, 50 (4b), pp 941-952 (Dec 1983)

KEY WORDS: Dynamic plasticity

Recent advances in the understanding of the dynamic plastic response of crystalline solids are discussed. At the level of individual dislocations progress is being made on measurements of dislocation mobility at high stress levels and on elastodynamics solutions for transient dislocation motions. More progress is required on the understanding of changes in mobile dislocation density during dynamic plastic deformation. Widespread use of the Kolsky (or split-Hopkinson) bar has resulted in a reasonably clear picture of the dependence of flow stress on plastic strain rate for polycrystalline metals deformed at strain rates up to 10^3 s^{-1}. Influences of strain-rate history, temperature, and pressure require further investigation.

85-175
A Précis of Developments in Computational Methods for Transient Analysis
T.J.R. Hughes, T. Belytschko
Stanford Univ., Stanford, CA 94305
J. Appl. Mech., Trans. ASME, 50 (4b), pp 1033-1041 (Dec 1983), 72 refs

KEY WORDS: Transient analysis, Reviews

Recent developments in computational transient analysis methodology are described. Emphasis is placed on fundamental properties of some of the most widely used algorithms. The techniques used to analyze their behavior and newer procedures that attain greater computational efficiency are described.

85-176
Stability of Dynamic Systems
H.H.E. Leipholz
Univ. of Waterloo, Waterloo, Ontario, Canada, N2L 3Gl
J. Appl. Mech., Trans. ASME, 50 (4b), pp 1086-1096 (Dec 1983), 1 fig, 32 refs

KEY WORDS: Stability, Reviews

The stability theory of dynamic systems, emerging from various beginnings strewn over the realm of mechanics, has developed into a unified, comprehensive theory for dynamic systems with a finite number of degrees of freedom. It is demonstrated how this theory could be adapted to the specific nature of stability problems involving continuous elastic systems. The need for such adaption is stressed by pointing to systems with follower forces. The difficulties arising from the fact that continuous systems are systems with an infinite number of degrees of freedom are emphasized. An adequate approach to a unified stability theory including also continuous systems is outlined.

85-177
Optimal Control of Linear Distributed Parameter Systems by Shifted Legendre Polynomial Functions
Maw-Ling Wang, Rong-Yeu Chang
National Tsing Hua Univ., Hsinchu, Taiwan, Rep. of China
J. Dynam. Syst., Meas. Control, Trans. ASME, 105 (4), pp 222-226 (Dec 1983), 4 tables, 13 refs

KEY WORDS: Optimum control theory, Continuous parameter method, Legendre functions

The optimal control problem of a linear distributed parameter system is studied by employing the technique of shifted Legendre polynomial functions. A partial differential equation is expanded into a set of ordinary differential equations for coefficients in the shifted Legendre polynomial expansion of the input and output signals. Expressing the performance index in terms of the expansion coefficients, an optimal control gain problem was transformed into a two point boundary value problem by applying the maximum principle. The two-point boundary value problem is reduced into an initial value problem, the solution of which can be easily obtained by the proposed computational algorithm. An illustrative example will be used to prove this point.

85-178
Time Finite Element Discretization of Hamilton's Law of Varying Action
R. Riff, M. Baruch
Technion--Israel Inst. of Tech., Haifa, Israel
AIAA J.,22 (9), pp 1310-1318 (Sept 1984)

KEY WORDS: Time domain method, Finite element technique

Hamilton's Law of Varying Action is used as a variational source for the derivation of finite element discretization procedure in the time domain. Three different versions of the proposed algorithms are presented and verified for accuracy and stability. The new operator, connected with the proposed algorithms, bears attractive properties of much greater accuracy than other existing stable methods and easy computer implementation. The work herein shows that the reservations expressed against the use of finite elements in time domain seem unjustified.

85-179
Time Integration of Structural Dynamics Equations: A Survey
K.C. Park
Lockheed Res. Lab., Palo Alto, CA
"Pressure Vessels and Piping: Design

Technology - 1982. A Decade of Progress." S. Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 277-291, 3 figs, 2 tables, 55 refs

KEY WORDS: Direct integration technique, Computer programs

Several theoretical and practical attributes are reviewed for design and computer implementation of direct time integration methods as a stand-alone integrator module. Attributes include interaction of the characteristics of structural dynamics equations with those of time integration formulas, error and stepsize control strategies. Also included are sequentially interchangeable adoption of both explicit and implicit integration modes. Nonlinearities amenable to a unified computer implementation and advanced solution procedures that promise potential in structural dynamics analysis are approximated. An attempt has been made to present a dual thought-process of the integrator designer and of the integrator user. The paper focuses on the need for the improvements of some of the attributes, which should enhance the reliability of the integrator module.

85-180
Eigenvector Algorithms for Structural Analysis
P.S. Jensen
Lockheed Res. Labs., Palo Alto, CA
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S. Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 293-300, 1 fig, 25 refs

KEY WORDS: Eigenvalue problems

A common form of large eigenvector problem arising in structural analysis is generalized, symmetric and sparse with at least one matrix definite (positive or non-negative definite). Forms of solution normally required are several eigenvectors corresponding to the smallest eigenvalues. A few eigenvectors corresponding to eigenvalues near a reference point in the spectrum andall eigenvectors corresponding to eigenvalues within a specified interval in the spectrum may be required. Algorithms suitable for one form of solution are not necessarily suitable for either of the other two forms. Several algorithms based on inverse iteration are discussed and evaluated with respect to the form of solution for which they are most suitable. Other approaches to both large and small general problems are also briefly discussed.

85-181
Parametric Excitation in a Self-Excited Vibration System (3rd Report, The Influence of Cubic Non-linearity)
S. Yano
Fukui Univ., 3-9-1, Bunkyo, Fukui, Japan
Bull. JSME, 27 (228), pp 1264-1271 (June 1984), 11 figs, 4refs

KEY WORDS: Subharmonic oscillation, Parametric excitation

In a self-excited vibration system with the restoring force expressed as the product of a nonlinear function of deflection and a periodically variable coefficient, parametric resonances and subharmonic vibrations occur. The influence of cubic non-linearity which is considered to induce subharmonic vibrations on such a system is investigated in detail. Approximate solutions of a system with the nonlinear restoring force expressed as a cubic function are determined by the previously reported method. Consideration of that system without a self-excitation suggests the occurrence regions of a subharmonic resonance of order 1/2 and parametric resonances of first and second orders.

85-182
Parametrical Resonances of First and Second Order in Vibration Systems with General Harmonic Excitation Matrices (Parameterresonanzen 1. und 2. Art bei Schwingungssystemen mit allgemeinen harmonischen Erregermatrizen
N. Eicher

Ing. Arch., 54 (3), pp 188-204 (1984), 1 fig, 9 refs (In German)

KEY WORDS: Parametric resonance, Harmonic excitation, Approximation methods

For a general linear vibration system with harmonic excitation matrices stability investigations are made using an analytic approximation method. For all parametric resonances of first order formulas describing the stability limits are given and discussed. Analytic expressions describing the limiting curves are deduced for parametric resonances of second order (resonances of sum and difference frequencies). The influence of mutual phase displacements on size and position of instability regions is investigated.

MODELING TECHNIQUES

85-183
Analytical Model Accuracy Requirements for Structural Dynamic Systems
Jay-Chung Chen
California Inst. of Technology, Pasadena, CA
J. Spacecraft Rockets, 21 (4), pp 36-373 (July/Aug 1984)

KEY WORDS: Mathematical models, Dynamic structural analysis

A test/analysis correlation criterion has been developed for the analytical model accuracy requirement for structural dynamic systems. It is based on the principle of equal errors from the model inaccuracy and the uncertainties of dynamic environments. The forcing functions are idealized to establish the base for uncertainty definition and the maximum allowable errors from these uncertainties are obtained. The model accuracy requirement is established by comparing the responses due to the model errors with those due to the forcing function uncertainties

NONLINEAR ANALYSIS

85-184
Qualitative Theory and Bifurcation to Chaotic Motions in Nonlinear Mechanics
P. Holmes
Cornell Univ, Ithaca, NY
U.S. National Congress of Appl. Mechanics, Proc. of the 9th, Cornell Univ, Ithaca, NY, June 21-25, 1982, ASME, 1982, pp 421-431, 14 figs, 51 refs

KEY WORDS: Nonlinear theories

Some aspects of the theory of dynamical systems are described and their use in the analyisis of problems in the nonlinear mechanics of solids and fluids is illustrated. Concentration is on recent results on strange attractors, persistent, apparently chaotic motions observed in sets of deterministic differential equations and mapping. Such attractors capture all solutions starting nearby. They have the property that solutions starting close together, while converging on the attracting invariant set, separate exponentially fast within that set and behave apparently independently.

STATISTICAL METHODS

85-185
On the Application of Liapunov's Direct Method to Discrete Dynamic Systems with Stochastic Parameters
G.J. Wiens, S.C. Sinha
Kansas State Univ., Manhattan, KS 66506
J. Sound Vib., 94 (1), pp 19-31 (May 8, 1984), 4 figs, 1 table, 17refs

KEY WORDS: Stochastic processes, Lyapunov's method

A Lyapunov function specially suitable for the study of the almost sure asymptotic stability of a class of linear discrete systems, described by a set of second order differential equations with stochastic parameters, is presented. A theorem and related corollaries, applicable to systems involving general types of forces, are obtained. The proposed technique is shown to be useful in minimizing the computational efforts associated with relatively large dynamic systems. Several examples, including systems involving follower forces, are includ-

ed to demonstrate the effectiveness of the method.

85-186
The Effect of the Markov Chain Condition on the Prediction of Extreme Values
A. Naess
Norwegian Hydrodynamic Labs., Valentinlyst, N-7001 Trondheim, Norway
J. Sound Vib., 94 (1), pp 87-103 (May 8, 1984)

KEY WORDS: Stochastic processes

The purpose of this paper is to study the effect of correlation on extreme value estimates of a narrow-band, stationary Gaussian process. This is done by introducing a Markov chain condition on the sequence of peak values of the process. It is shown that this leads to extreme value estimates that are smaller than those obtained by standard order statistics. Under specified conditions, an explicit formula is obtained for the extreme value estimates resulting from the introduction of the Markov chain condition. Due to the close connection between extreme value statistics and first passage time statistics, a discussion of the impact of the results on the first passage time problem is also given.

PARAMETER IDENTIFICATION

85-187
Identifiability of Nonlinear Systems with Hysteretic Elements
A.M. Andronikou, G.A. Bekey, F.Y. Hadaegh
Rockwell International, Downey, CA
J. Dynam. Syst., Meas. Control, Trans. ASME, 105 (4), pp 209-214 (Dec 1983) 5 figs, 13 refs

KEY WORDS: System identification techniques, Hysteretic damping

This paper is concerned with the conditions under which deterministic systems containing a hysteresis-type nonlinearity are identifiable from input-output measurements. The approach to the problem requires that identifiability conditions for appropriately defined nearly-equivalent systems be obtained initially. Then conditions under which identifiability of the nearly-equivalent nonlinear (but nonhysteretic) system imply the identifiability of the original hysteretic system are obtained. Sufficient conditions for identifiability of these systems are presented.

85-188
System Identification of Structures with Joint Rotation
J.S. Dimsdale
Univ. of California, Berkeley, CA
Rept. No. UCB/EERC-83/16, NSF/CEE-83020, 111 pp (July 1983) PB84-192210

KEY WORDS: System identification techniques, Joints, Earthquake response

The role of joint behavior in the identification of frame models from dynamic response data caused by seismic forcing functions is investigated. An optical method is devised for accurately measuring joint rotation of a structure during earthquake excitation. This method is applied to a simple six story frame in which the columns have approximately the same stiffness as the girders. Response data is collected for a variety of base motion histories. Also studied are data previously collected from a three story frame in which joint rotation information is inferred from strain measurements. A number of different mathematical models of these structures are evaluated using system identification.

85-189
Damage Assessment from Dynamic Response Measurements
J.T.P. Yao, S. Toussi, M.A. Sozen, Purdue Univ., West Lafayette, IN
U.S. National Congress of Appl. Mechanics, Proc. of the 9th, Cornell Univ., Ithaca, NY, June 21-25, 1982, ASME, 1982, pp 315-322, 5 figs, 64 refs

KEY WORDS: Parameter identification technique, Damage

The objective of this paper is to present the state-of-the-art on damage assessment of existing structures from the authors' viewpoint. Relevant literature is critically reviewed. Recent research results on mathematical formulation and identification of interstory hysteretic behavior are summarized and presented. The emphasis of this paper is on the analysis and usage of dynamic response measurements for damage assessment purposes.

OPTIMIZATION TECHNIQUES

85-190
Treatment of General Boundary Conditions and Point-Wise State Variable Constraints in Optimum Design for Static and Dynamic Response
C.C. Hsieh, J.S. Arora
Computer-Aided Engrg. Instructional Lab., Univ. of Iowa, Iowa City, IA
Rept. No. CAD-SS-84-1, NSF/CEE-84003, 245 pp (Jan 1984) PB84-192749

KEY WORDS: Optimum design, Boundary condition effects, Dynamic response

Design sensitivity analyses are presented with general boundary conditions for static response problems and for linear dynamic problems. Difficulties in treating equivalent functional constraints for the point-wise state variable constraints are noted, and ideas for handling such constraints are suggested. An optimization of general response problems is provided, with the worst-case design formulation and the hybrid formulation for the point-wise state variable constraints. The treatment of point-wise state variable constraints in distributed parameter problems is discussed.

DESIGN TECHNIQUES

85-191
Inverse Perturbation Method for Structural Redesign with Frequency and Mode Shape Constraints
C.J. Hoff, M.M. Bernitsas, R.E. Sandstrom, W.J. Anderson
Univ. of Michigan, Ann Arbor, MI
AIAA J., 22 (9), pp 1304-1309 (Sept 1984) 5 figs, 1 table, 15 refs

KEY WORDS: Structural modification techniques, Natural frequencies, Mode shapes, Perturbation theory

A procedure is described for the redesign of undamped structural systems to meet natural frequency and/or mode shape objectives. The procedure can be applied to large or small modal changes and is based on a single finite element analysis of the baseline system. Perturbation of the baseline system is used to develop a set of equations that characterize the redesign process. Depending on the number of modal objectives and design variables, the problem is formulated as underconstrained, properly constrained, or overconstrained. All three problems are solved using an incremental predictor-corrector technique within the feasibility domain defined by the practical constraints imposed on the design variables. The procedure is illustratetd by the redesign of a 1254 degree-of-freedom casting for a frequency objective.

COMPUTER PROGRAMS

85-192
Analysis of HCDA
Y.W. Chang
Argonne National Lab., Argonne, IL
"Pressure Vessels and Piping: Design Technology - 1982. A Decade of Progress." S.Y. Zamrik and D. Dietrich, eds., ASME-PVD, 1982, pp 333-341, 4 figs, 58 refs

KEY WORDS: Computer programs, Nuclear reactors, Nuclear reactor safety

This paper deals with the development of computer programs for the hypothetical core-disruptive accident (HCDA) analysis and their applications to liquid metal fast breeder reactors.

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29-May 3 31st Annual Technical Meeting and Equipment Exposition [IES] Las Vegas, NV ***(IES Hqs.)***

MAY 1985

6-8 4th International Symposium on Hand-Arm Vibration [Finnish Inst. of Occupational Health] Helsinki, Finland ***(I. Pyykko, Inst. of Occupational Health, Laajaniityntie 1, 01620, Vantaa 62, Finland)***

6-9 American Society of Lubrication Engineers, 40th Annual Meeting [ASLE] Las Vegas, NV ***(ASLE Hqs.)***

22-24 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] New Orleans, LA ***(Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)***

JUNE 1985

3-5 NOISE-CON 85 [Institute of Noise Control Engineering and Ohio State University] Columbus, OH ***(NOISE-CON 85, Dept. of Mech. Engrg., Ohio State Univ., 206 W. 18th Ave., Columbus, OH 43210 - (614) 422-1910)***

24-26 2nd National Conference and Workshop on Tailoring Environmental Standards to Control Contract Requirements [IES] Leesburg, VA ***(IES Hqs.)***

JULY 1985

2-4 Ultrasonics International '85, Kings College, London ***(Z. Novak, Ultrasonics, P.O. Box 63, Westbury House, Bury St., Guildford, Surrey GU2 5BH, England)***

11-13 International Compressor Engineering Conference, Lafayette, IN ***(Purdue University, W. Lafayette, IN - (317) 494-2132)***

AUGUST 1985

5-10 SAE West Coast International Meeting [SAE] Portland, OR ***(SAE Hqs.)***

SEPTEMBER 1985

1-4 Beijing International Gas Turbine Symposium and Exposition [ASME Gas Turbine Div., Chinese National Aero-Technology Import and Export Corp., and Chinese Soc. of Aeronautics and Astronautics] Beijing, People's Rep. of China ***(International Gas Turbine Center, 4250 Perimeter Park South, Suite 108, Atlanta, GA 30341 - (404) 451-1905)***

9-11 19th Midwestern Mechanics Conference [Ohio State University] Columbus, OH ***(Dept. of Engineering Mechanics, Ohio State Univ., 155 W. Woodruff Ave., Columbus, OH 43210 - (614) 422-2731)***

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335 E. 45th St.
New York, NY 10017

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United Engineering Center
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ASLE: American Society of Lubrication Engineers
838 Busse Highway
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Philadelphia, PA 19103

ICF: International Congress on Fracture
Tohoku University
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
United Engineering Center
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IES: Institute of Environmental Sciences
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IMechE: Institution of Mechanical Engineers
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IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
67 Alexander Dr.
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SAE: Society of Automotive Engineers
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Warrendale, PA 15096

SEE: Society of Environmental Engineers
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14 Fairfield Dr.
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SPE: Society of Petroleum Engineers
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>
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1. Pincer, M.F., "Transonic Blade Flutter - A Survey," Shock Vib. Dig., 7 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Dev. (1960).
4. Lin, C.C., Reissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," J. Math. Phys., 27 (3), pp 220-231 (1948).
5. Landahl, M., Unsteady Transonic Flow, Pergamon Press (1961).
6. Mills, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," J. Aeronaut. Sci., 23 (7), pp 671-678 (1956).
7. Lees, L., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," J. Aeronaut. Sci., 22 (1), pp [illegible] (1955).

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